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Living Together in Space: The Design and Operation of the Life Support Systems on the *International Space Station*

P.O. Wieland

жить Вместе в Космосе: Проектирование и функционирование Системы Поддержки Жизни на Международной Космической Станции

Zusammenleben im Weltraum: Der Entwurf und Betrieb der Lebenserhaltungsysteme auf der internationalen Weltraumstation

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National Aeronautics and Space Administration
Marshall Space Flight Center • MSFC, Alabama 35812

January 1998

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On the Cover

The cover illustration shows the *International Space Station (ISS)* in low-Earth orbit with the space shuttle docked to Node 2 and two Soyuz vehicles docked to the Russian Segment. The Earth's horizon represents that earth-observation will be one activity performed from the *ISS*, that the research performed on board the *ISS* will benefit everyone on Earth, and that this project is a cooperative venture involving many nations. The international cooperation required for the *ISS* project is also indicated by the translations of the document title into the languages of the primary partners. The Moon, Mars, and stars in the background represent that astronomical observation will also be an activity performed from the *ISS*. In addition, they represent the potential for future cooperative projects, including deep space missions and returning people to the Moon and sending crews to Mars.

A Parable

There is a story about a man who left this Earth and was taken on a tour of the inner realms. He was shown a room where he saw a large group of hungry people trying to eat dinner, but because the spoons that they were trying to eat with were longer than their arms, they remained frustrated and hungry.

"This," his guide told him, "is Hell."

"That's terrible!" exclaimed the man.
"Please show me Heaven!"

"Very well," agreed the guide, and on they went.

When they opened Heaven's door, the man was perplexed to see what looked very much like the same scene: there was a group of people with spoons longer than their arms. As he looked more closely, however, he saw happy faces and full tummies, for there was one important difference: the people in Heaven had learned to feed each other.

—From *The Dragon Doesn't Live Here Anymore*,
by Alan Cohen

Существует легенда о человеке, который покинул Эемло и получил воэможность оцмотреть иные миры. Ему покаэали комнату, в которой он убидел большую группу ролодных людей, пытающихся съесть обед, но поскольку ложки, которым они пытались есть, были длиннее чем их руки, они оставались голодными и расстроен ными.

"Это," скаэал ему сопровождаюоий, "и есть Ад."

"Это ужасно!" воскликнул человек. "Пожалуйста, покажи мне Рай!"

"Прекрасно," согласился сопровождающий, и они полетели.

Когда они открыли дверь в Рай, человеку покаэалось, что то, что он увидел, выглядело очень похожим на предыдущую сцену: там была группа людей с ложками длиннее чем их руки. Однако, когда он присмотрелся поближе, он увидел счастдивые лица и попные животики, и для этого выло одно важное отличие от предыдущего: люди в Раю научились кормить друг друга.

—иэ книги Алана Кохена "дракон эдесь больше не живет"
(перевод ильи жадовецкого)
(Translated by Ilya Zhadovetsky)

これは、この世を去りあの世へ旅立った一人の男の物語りです。
その男は、一つの部屋を見せられました。　その部屋の中では、
多くのお腹をすかした人達が、ご飯を食べようとしていました。
しかし、彼等の使っているスプーンは、彼等の腕より長くて
旨く使う事が出来ずに空腹のまま困っていました。
「ここは地獄です。」と、ガイドが言いました。
「なんて恐ろしいんだ。どうか、天国を見せてください。」
と、男は叫びました。
「よろしい。」と、ガイドは言い、彼等は天国へ行きました。
彼等が天国へのドアーを開けた時、男は地獄で見た景色に非常に
似ていたので当惑していました。
そこには、自分達の腕より長いスプーンを持った人達がいました。
しかし、男が、その人達をよく見ると、一つの違いを見付けました。
それは、彼等は、皆幸福で満腹でした。
彼等は、お互いを食べさせる事を習ったのです。

ーー　アラン・コヘンの「ドラゴンは、もうここに住んでいない。」より

(Translated by Kazuo "Ben" Hayashida)

Hier ist die Geschichte von einem Mann der von der Erde Abschied nahm, und er wurde auf eine Tour des Jenseits gefuehrt. Sein Begleiter brachte ihn zu einem Raum, wo eine grosse Gruppe von ausgehungerten Leuten versuchte zu essen. Sie konnten aber nichts in ihren Mund bekommen, denn ihre Loeffel waren laenger als ihre Arme. Sie blieben hungrig und verzweifelt.

"Dies ist die Hoelle" erklaerte sein Begleiter.

"Das ist schrecklich" rief der Mann.

"Bitte, zeig mir den Himmel!"

"Sicher," sagte der Begleiter, und sie gingen weiter.

Als sie die Himmelstuere oeffneten, war der Mann voellig verwirrt. Was er sah schien die gleiche Szene zu sein wie zuvor: Eine Gruppe von Leuten mit Loeffeln laenger als ihre Arme. Bei naeherem Zusehen sah er aber frohe Gesichter und volle Baeuche, denn hier war ein bedeutender Unterschied: Die Leute im Himmel hatten gelernt sich gegenseitig zu fuettern.

Aus: "Der Drache wohnt hier nicht mehr," von Alan Cohen
(Translated by Werner Dahm)

On raconte l'histoire d'un homme qui, ayant quitté notre Terre, eut la chance de visiter les royaumes éternels. On lui montra une pièce où une multitude de gens affamés étaient assemblés pour dîner, mais parce que leurs cuillers étaient plus longues que leurs bras, ils demeuraient frustrés et à jeun.

"Voici l'Enfer!" expliqua son guide.

"C'est horrible!" s'écria l'homme.

"Montrez-moi vite le Paradis!"

"Entendu," acquiesca le guide, et ils s'en furent.

Quand ils ouvrirent les portes du Paradis, l'homme s'étonna de voir devant lui une scène presque identique: une foule de gens avec des cuillers plus longues que leurs bras. Mais, après un examen plus attentif, il vit l'air content des visages et les ventres pleins à cause d'une différence importante:

les gens du Paradis avaient appris à se nourrir les uns les autres.

—d'après *The Dragon Doesn't Live Here Anymore*,
par Alan Cohen
(Translated by Laurent Sibille)

C'è una storia di un uomo che lasciò questa terra e prese parte a un viaggio al l'interno del regno dei cieli. Gli venne mostrata una stanza dove vide un grup po di persone affamate che si apprestavano a consumare una cena, ma, poichè i cucchiai con cui cercavano di mangiare erano più lunghi delle loro braccia, essi rimanevano frustrati ed affamati.

"Questo," gli disse la Guida, "è l'Inferno."

"È terribile!" esclamo l'uomo.

"Per favore fammi vedere il Paradiso!"

"Molto bene," concordò la Guida e si incamminarono.

Aperta la porta del paradiso, l'uomo fu perplesso nel vedere quella che sembrava la stessa scena: c'erano un gruppo di persone con i cucchiai più lunghi delle loro braccia. Tuttavia, guardando più da vicino, vide faccie felici e pancie piene.

Con una differenza importante:

La gente in Paradiso aveva imparato a imboccarsi l'un con l'altro.

—da "Il Drago non vive più qui" di Alan Cohen
(Translated by Franco Pennati (Alenia/ASI))

PREFACE

The *International Space Station* (*ISS*) incorporates elements and features from the planned Space Station *Freedom*, under development by an international consortium led by the United States (U.S.), and the planned *Mir-2*, under development by Russia, with modifications to make them complementary. With this increased cooperation between Russia, the United States, and the other international partners on the *ISS* project, understanding the designs and methods of design of the other partners is crucial for project success.

Some of the functions of the *ISS* are performed by parallel but separate systems. Environmental Control and Life Support (ECLS) is one system in which functions are performed independently on the Russian Segment (RS) and on the U.S./international segments of the *ISS*. During the construction period, the RS has the capability for waste processing and water purification before the U.S./ international segments and, for that period of time, supports the entire *ISS* for those functions. Also during that period, the Russians provide oxygen and nitrogen for metabolic consumption and structural leakage.

This report describes, in two volumes, the design and operation of the ECLS Systems (ECLS) used on the *ISS*. Volume I is divided into three chapters. Chapter I is a general overview of the *ISS*, describing the configuration, general requirements, and distribution of systems as related to the ECLSS. It includes discussion of the design philosophies of the partners and methods of verification of equipment. Chapter II describes the U.S. ECLSS and technologies in greater detail. Chapter III describes the ECLSS in the European Attached Pressurized Module (APM), Japanese Experiment Module (JEM), and Italian Mini-Pressurized Logistics Module (MPLM). Volume II describes the Russian ECLSS and technologies in greater detail. (Volume II distribution is restricted to use within the contractual agreement between the United States and Russia.)

This report addresses the following questions relating to the *ISS* ECLS systems:

- How does the *ISS* design, in general, affect the ECLSS design?
- What requirements are placed on the ECLSS?
- What design philosophies are used in planning the different ECLS systems?
- What ECLS technologies are used?
- What are the designs of the ECLS systems and how do they operate?
- How do the ECLSS capabilities change during the assembly of the *ISS*?
- How is the ECLSS verified?
- What safety features are included in the ECLSS?
- What are the procedures for responding to a failure?
- How is the ECLSS maintained?

This report contains information that was available as of June 1996 with some updates as of September 1997. Every effort was made to ensure that the information is accurate; however, not all of the *ISS* ECLSS details were finalized at that time. See the Bibliography for references used in preparing this document.

To receive corrections and updates, or to suggest changes, please contact the author. Comments regarding this report are invited and may be sent to the author at NASA/MSFC/ED62, Marshall Space Flight Center, AL 35812; or via e-mail: Paul.O.Wieland@msfc.nasa.gov.

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ABBREVIATIONS, ACRONYMS, DEFINITIONS, AND TRANSLATIONS

(RS) indicates that a term refers to the Russian Segment or equipment
(USOS) indicates that a term refers to the U.S. Segment or equipment
(APM) indicates that a term refers to the ESA segment or equipment
(JEM) indicates that a term refers to the Japanese segment or equipment
(MPLM) indicates that a term refers to the Italian segment or equipment

A	aft
A	ampere(s), Ампер
A	analysis (verification method)
AAA	Avionics Air Assembly (USOS, APM, JEM)
absorbent	абсорбент или всасывающий
ABU	After-Burn Unit, of the Elektron water electrolyzer (RS)
AC	Assembly Complete; the final stage of *ISS* construction
AC	Assembly Compartment, of the SM, with equipment and storage tanks outside the pressure shell (RS)
ACF	active components filter; part of the commode/urinal (RS)
ACRV	Assured Crew Return Vehicle, космиче ский корабль для аварийного возбращения
ACS	Atmosphere Control and Supply, регулирование атмосферы (USOS)
ACS	Atmospheric Cleansing System, Сицтема Очицтки Атмосферы (СОА) (RS)
ACS	Air Conditioning System (RS)
Ag	silver, серебро
AH	Atmosphere Heater; part of the shower facility (RS)
AL	Airlock, воздушный шлюз
amp	ampere(s) (see A)
APM	Attached Pressurized Module; European laboratory module (APM), also Columbus Orbital Facility (COF)
AR	Atmosphere Revitalization, компенсация атмосферы (USOS)
ARS	Atmosphere Revitalization Subsystem, система компенсация атмосферы
ASF	amps per square foot; current density in water electrolyzers
ASI	Agenzia Spaziale Italiana, the Italian Space Agency
assembly (noun)	агрегат
ATM	atmosphere (on the USOS C&W panel)
atm	atmospheres of pressure
ATU	Audio Terminal Unit
AVS	Atmosphere Ventilation System (RS)
ball area	Location in the SM (and UDM) that serves as an AL prior to installation of the DC (RS)
BIT	built-in-test; the capability for automatic verification of proper operation of electronics or components; встроенная система контроля
brushless motor	An electric motor that does not use brushes to transfer electricity to the rotor
BV	Bleed Valve; part of the ACS (USOS)
°C	degrees Celcius, градусов цельсия
C	carbon
Ca	calcium; a measure of water quality (mg/L), кальциий (мг/л)
cabin	Open space in a module, гермоотсек с экилажем
campout	Period prior to an EVA when astronauts, in the AL, breath an oxygen-rich atmosphere to remove excess N_2 from their blood
CC	Command Console (RS)

cc	cubic centimeter(s), кубический сантиметр
CCAA	Common Cabin Air Assembly (USOS)
CDD	Capability Description Documents
C&C MDM	Command and Control Multiplexer/Demultiplexer (USOS)
C&DH	Command and Data Handling (USOS)
C&W	Caution and Warning, Оповещрения и Предупреждения
CDRA	Carbon Dioxide Removal Assembly, агрегат удаления дбуокиси углерода (диоксида)
cfm	cubic feet per minute; U.S. measure of air flowrate
CFU	Colony Forming Unit, for quantifying the presence of bacteria, количество колокиеобразующих формирований (бакетерий, микроорганизмов), общее количество микробов
CFU/cm^3	Measure of the concentration of microorganisms (KOE/cm^3)
CGSE	Common Gas Support Equipment
CH_4	methane, метан
CHeCS	Crew Health Care Subassembly, комплекс средств (система), направленных на поддержание здоровья зкипажа (USOS)
CHRS	Central Heat Rejection System, централлизованная система теплоотвода (ЦСТО) (WCNJ) (RS)
CHTS	Central Heat Transport System (RS)
CHX	Condensing Heat Exchanger, Блок Сепарации Конденсата (БСК) (condensation separation unit)
CIL	Critical Items List
CKB	air conditioning and humidity removal assembly (RS)
cm	centimeter(s), сантиметр
CM	Core Module (of the *Mir*)
CO	carbon monoxide, окись углерода
CO_2	carbon dioxide, двуокись углерода
COD	Chemical Oxygen Demand; water quality parameter; a measure of the oxidizability of $K_2Cr_2O_7$, окисляемость
COF	Columbus Orbital Facility (see APM)
COF_2	carbonyl fluoride
color	Measure of water purity, цветность, measured in degrees, градусы
Columbus	ESA segment of the *ISS* (see APM)
CP	Control Panel
CPS	Cabin Pressure Sensor (USOS)
CPU	Central Processing Unit, of a computer, центральный вычсслытельное устройство
crew systems	Operation or other activity performed by the crew on the ECLS or other system; sometimes referred to as "man systems" (USOS)
CRES	corrosion resistant steel
CRF	Contamination Removal Filter (RS)
CS	Current Stabilizer (on the Elektron) (RS)
CSA	Canadian Space Agency
CSPU	Condensate Separation and Pumping Unit (RS)
CTCU	Cabin Temperature Controller Units (APM)
CTV	Crew Transfer Vehicle, Корабль "Союз" или транспортный корабль
CWP	Caution and Warning Panel
CWRS	Condensate Water Recovery Subsystem (RS)
CWSA	Condensate Water Separation Assembly
D	demonstration (verification method)
DA	Depressurization Assembly
dc	direct current, Постоянный ток (ПТ)
DC	Docking Compartment (RS), стыковочный отсек

depressurization	разгерметизация
detect.	detection
DHU	Distribution and Heating Unit, for dispensing water (RS)
dia.	diameter, диаметр
DM	See UDM
dp	change in pressure
DSM	Docking and Stowage Module, модуль складской (RS)
Dyuza–1M	atmosphere leakage monitoring system on the *Mir* (Дюза–1M)
EAL	Experiment Airlock (JEM)
ECLS	Environmental Control and Life Support, регулирования окружающих условий и жизнеобеспечения
ECLSS	ECLS System, Система Обеспечения Жизнедеятелъности (СОЖ) и управления окружающей средой
ECS	Environmental Control System, Система Регулирования Окружающих условий (CPO)
едв	Russian potable water tanks (22 L) (pronounced yeh-deh-veh) (RS) Emkoctb Для Воды
EF	Exposed Facility (JEM)
EHE	Evaporative Heat Exchanger, of the CHRS (RS)
EHL	External Hydraulic Loops, of the TCS (RS)
EHS	Environmental Health System, система поддержания юригоной для здоровья среды
EHS	Environmental Health Services
EIB	Electrical Interface Box (USOS)
ELM	Experiment Logistics Module (JEM)
ELM–ES	Experiments Logistics Module-Exposed Section (JEM)
ELM–PS	Experiments Logistics Module-Pressurized Section (JEM)
ELPS	Emergency Lighting Power Supply (MPLM)
EMI	electromagnetic interference
EMU	Extravehicular Mobility Unit, for EVA support; spacesuit
EP	Electrolysis Plant (Elektron O_2 generator) (RS)
EP	ИП, airflow meter designation (RS)
EPS	Electrical Power System
EPVV	Electrolysis Plant Vacuum Valve, on the Elektron O_2 generator (RS)
ESA	European Space Agency, европейское космическое агентство
ESD	Electroinductive Smoke Detector, избещатель пожара дымовой электроиндукционный (ИДЭ-2) (RS)
ETFE	ethyltetrafloroethylene
EVA	Extravehicular Activity, внекорабельная деятельность космонавтов (ВКД) (Работа В Открытком Космосе Или Выход В Открыткый Космос)
EWP	Emergency Warning Panel, пульт аварийной пожарной сигнализации (ПАПС) (in the RS SM)
°F	degrees Fahrenheit, температурная щкала фаренгейта, по щкале фаренгейта
F	forward
fan	вентилятор
FC	firmware controller
FDS	Fire Detection and Suppression, обнаружение юпжара и подавление, система пожарообнаружения (СПО) (Fire Detection System), система пожаротушения (Fire Suppression System)
FDI	Fault Detection and Isolation, определение и изоляция
FDIR	Fault Detection, Isolation, and Recovery
feedthrough (noun)	A fluid line or electrical line that is connected through a hole in a bulkhead or panel
FGB	Functional Cargo Module, фунциональный Грузовой Блок (фГБ); built by Russia
FMEA	Failure Modes and Effects Analysis
FS	full scale
FSP	Fire Suppression Port

ft^2	square feet
ft^3	cubic feet
FVI	FDS Volume Indicator (MPLM)
g	gram(s); metric unit of mass
G	gravity; acceleration due to gravity at the Earth's surface
GA	Gas Analyzer (RS), Газоанализатор (ГА)
GA–E	Gas Analyzer-Elektron; the device that analyzes for H_2 in the O_2 outlet (GA–E H_2) or for O_2 in the H_2 outlet (GA–E O_2) (RS)
GACU	Gas Analyzer Control Unit, for the atmosphere monitoring GA's (RS)
GAMU	Gas Analyzer Monitoring Unit, for the Elektron GA (RS)
GC/IMS	Gas Chromatograph/Ion Mobility Spectrometer
GCP	Gas Control Panel (RS)
GCSS	Gas Composition Support System (RS)
GFE	Government Furnished Equipment; provided by NASA to contractors; may be designed and fabricated by another contractor (USOS)
GLA	General Luminaire Assembly (MPLM)
GLHE	Gas-Liquid Heat Exchanger (component of the Vozdukh) (RS)
GLHEA	Gas-Liquid Heat Exchanger Assembly
GLM	gas/liquid mixture, газожидкостная смесь (гжс)
GLMF	Gas/Liquid Mixture Filter (RS), Фильтр Газожидкости смеси (ФГС)
GLS	Gas/Liquid Separator, газожидкостной разделнтель
gore panel	pressure shell of modules
gpm	gallons per minute (U.S. measure of liquid flowrate)
gr	grain(s) of water; a measure of the amount of water in air (1gr=0.0648g)
hr	hour(s)
H_2	hydrogen, водород
Hab	U.S. Habitation module containing a galley, exercise and recreational facilities, and other non-laboratory functions; Бытовой Отсек (USOS)
habitat	pressurized living and working quarters of the *ISS*, Обитаемый Отсек
hardness	water quality measurement; see total hardness
HCF	Hazardous Contaminants Filter (RS)
HCl	hydrogen chloride
HCN	hydrogen cyanide
HCU	heater control unit (MPLM)
hdwe	hardware, железный и медный товар
HEPA	High Efficiency Particulate Atmosphere filters to remove particulates and microorganisms from the atmosphere, воздух с вычокой степенью очистки от пыли, макрочастиц, (противопыльный фильтр)
HEU	Human Equivalent Unit (regarding metabolic activity)
HF	hydrogen fluoride
hp or HP	high pressure
hPa	hecto-Pascals, (metric measure of pressure)
HTCO	High-Temperature Catalytic Oxidizer (of the TCCS), высокотемпературный каталитический окислителъ (USOS)
HX	Heat Exchanger, to transfer heat from one fluid (gas or liquid) to another
HXLS	Heat Exchanger Liquid Sensor, водяной детестор теплообменника
I	inspection (verification method)
IBMP	Institute of BioMedical Problems, Институт медико-биологических проблем, Russian agency concerned with the medical and biological safety of the cosmonauts
ICD	Interface Control Document
ID	inner diameter
I/F	interface; electrical, data, or fluid connection

IHL	Internal Hydraulic Loops (of the TCS) (RS)
II	Indicator Instrument, part of the shower facility (RS)
IMS	Ion Mobility Spectrometer
IMV	Intermodule Ventilation, междумодульная вентиляция
in	inch(es); U.S. measure of distance
in H_2O	inch(es) of water; measure of ΔP
integration	интерграция
interface	интерфейс
I/O	Input/Output data exchange, вход/быход (сигнала), ввод/вывод (данных)
iodine	йод
IPB	Information Processing Block
IR	infrared radiation, инфракрасная раднация
ISOV	IMV Shutoff Valve
ISPR	International Standard Payload Rack, полезная нагрузка стойка, стоек
ISS	*International Space Station*, Международная Космическая Станция (МКС)
ITCS	Internal Thermal Control System, система терморегулированую внутренний, внутренний контур системы терморегулированую
jam-nut	A nut that is thinner than standard nuts; often, two jam-nuts are used together to ensure that they do not loosen
JEM	Japanese Experiment Module, японский экспериментальный (лабораторный) модуль
jumper	A duct or hose that connects fluid lines
KAB	Конденсат Атмосферной Благи, humidity condensate (Russian acronym)
kg	kilogram(s); metric measure of mass; килограмм
KHPA–63	chemical absorbent in the HCF (RS)
KOKOR	plant growth facility' "conveyor greenhouse;" Конвейериая Косиигесиа Оранжерея, КОКОР, "ВИТАЦИКЛ" or "Vitacycle" (RS)
kPa	kilo-Pascal(s); metric measure of pressure, килопаскаль
Kvant	pressurized module attached to the *Mir* space station, Квант
$K_2Cr_2O_4$	potassium chromate
L	liter(s); metric measure of volume, литр
Lab	The U.S. module containing experiment racks and other scientific equipment, лабораторный модуль США (USOS)
lb	pound(s), U.S. measure of mass, фунт
LED	light emitting diode
LEL	Lower Explosive Limit
LLI	Liquid Leak Indicator; part of the commode/urinal (RS)
LSF	Life Support Facility, Средства Обеспечения Жизнидеятельности (СОЖ)
LiOH	lithium hydroxide, Гидроокиси лития (for CO_2 and trace contaminant removal from the atmosphere)
LSM	Russian Life Support Module, модуль жизнеобеспечения (МЖО) (RS)
LSS	Life Support System, Система Обеспечения
LTCO	Low-Temperature Catalytic Oxidizer
LTL	Low-Temperature Loop; part of the ITCS (USOS)
LU	Liquid Unit, of the Elektron (RS)
LV	valves in the Elektron O_2 generator (RS)
LVPT	Linear Variable Pressure Transducer
LWR	Liquid Waste Receptacle
m	meter(s), метр (metric measure of distance)
$\dot{m}$	mass flowrate
	Жизнедеятелъности (СОЖ)
M	motor

mA milli-Ampere

MAC Maximum Allowable Concentrations of gaseous trace contaminants, максималъно допустимая концентрация

magnesium магний, used as a water quality parameter measured in mg/L (мг/л)

man-system See crew-system

manual (verb) ручной, без применения механизмов

manual valve ручной клапан

max maximum

MCA Major Constituent Analyzer, анализатор основных составляющих (атмосферы)

MCL Maximum Contamination Level, предельно дапустимая концентрация, максимально допустимые уровни микропримнсей

MCV Microbial Check Valve

MDM Multiplexer/Demultiplexer, data transfer equipment

MHP separator pump (RS)

min minute(s), минута(ы), мин

min. minimum

Mir Russian space station, Мир, translated "Peace"

MIRU Micro-Impurity Removal Unit; part of the TCCS (RS)

mKm a unit of pressure change measurement by the Dyuza, 25 mKm Hg/sec = 90 mmHg/h

MLI multilayer insulation

MLS Mostly Liquid Separator; part of the WP (USOS)

mm millimeter(s); миллиметр; metric measure of distance

MMH maintenance man-hours

mmHg millimeters of mercury, миллиметр ртутного столба

mo month(s)

mod moderate (adjective)

MPEV Manual Pressure Equalization Valve, ручой клапан выправнивания давления (USOS)

MPI Magnetic Position Indicator

MPLM Mini-Pressurized Logistics Module (built by Italy)

mS/cm milliSiemans per centimeter; measure of electrical conductivity; a measure of water quality

MSC Module Systems Console (RS)

MSS Mobile Servicing System

MTBF Mean Time Between Failures, for determining the reliability of components

MTL Moderate Temperature Loop; part of the ITCS (USOS)

MWP Module Warning Panel, Пульт Управления и Сигнализации (ПУС) (RS)

n nadir; direction, vertically beneath

N Newton(s) (metric unit of force)

N1 Node 1

N2 Node 2

N_2 nitrogen, азот

N/A not applicable

NASA National Aeronautics and Space Administration, Национальное Управленно По Азронавтике и Исследованию Космического Пространства (НАСА)

NASDA National Space Development Agency (Japan)

NC normally closed

NH_3 ammonia, аммиак

NIA Nitrogen Interface Assembly, азот соединительный блок (USOS)

NIV Nitrogen Isolation Valve (USOS)

node узлов

Norm normally

NPRA Negative Pressure Relief Assembly

NPRV Negative Pressure Relief Valve

NTU Nephelometric Turbidity Unit; water quality parameter; единицы мутности, определенной нефелометрическим способом

O_2 oxygen, кислород

OACS Onboard Automation Control System (RS)

OCCS	Orbital Complex Control System (RS), система управления бортовым комплексом (субк)
OCS	Onboard Control System
OCP–4	Russian PFE (RS)
OECS	Onboard Equipment Control System; part of the OCCS; Система Управления Бортовой Аппаратурой (СУБА) (RS)
OGA	Oxygen Generation Assembly, Система получсния кислорода
OIV	Oxygen Isolation Valve (USOS)
OMS	Onboard Measurement System (RS)
ops	operations
O/R	override
ORCA	O_2 Recharge Compressor Assembly (USOS)
ORU	Orbital Replacement Unit; several components attached together and treated as a single part (USOS)
OSA	Oxygen Supply Aids (RS)
OSS	Oxygen Supply Subsystem, Система лодачи кислорода (RS)
OWF	(RS)
OWMSU	Oxygen/Water Mixture Separation Unit (RS)
P	pressure
PAV	Process Air Valve (USOS)
PBA	Portable Breathing Apparatus, партативная маска для дыхания
pc	particle count
PCA	Pressure Control Assembly, агрегат регулирования давлекия (USOS)
PCA	Purification Column Assembly (RS)
PCP	Pressure Control Panel, панель управрения наддувом
PCRA	Pressure Control and Regulation Aids (RS)
pcs	pieces, отрезок
PCS	Portable Computer System (USOS)
PCU	Purification Column Unit
PCV	Pressure Control Valve
PCWQM	Process Control Water Quality Monitor, индикатор качества воды (USOS)
Pd	paladium
PDB	Power Distribution Box (MPLM)
PDGF	Power Data Grapple Fixture (where RMS attaches)
PEP	Portable Emergency Provisions
PEV	Pressure Equalization Valve, клапан выправнивания давления
PFE	Portable Fire Extinguisher, портативный огнетушитель; also, the act of extinguishing a fire, пожаротушения
PFU	Plaque Forming Unit; quantifies virus populations
PGU	A component of the Elektron (RS)
pH	hydrogen ion concentration in an aqueous solution, активная реакция
PHF	Personal Hygiene Facility (RS)
PI	proportional-integral, control algorithm for temperature control (USOS)
PM	Pressurized Module, Japanese laboratory module (JEM)
PMA	Pressurized Mating Adapter, герметизирующий соедини тельныи адаптер
PMC	Parameters Monitoring Console (on the *Mir*)
POC	Pressing Out Collector; static water separator of the commode; сборщик с отжи (СОТ), (RS)
port	direction; left-hand side, facing forward
portable	портативный или переносный
potable water	питьевая вода
ppb	parts per billion
$ppCO_2$	partial pressure of carbon dioxide
pph	pounds per hour
ppm	parts per million, одна часть на миллион частей
ppO_2	partial pressure of oxygen
PPR	Positive Pressure Relief
PPRA	Positive Pressure Relief Assembly

PPU	Portable Pressurization Units; repressurizes the AL in emergency situations (RS)
Progress	Корабль "Прогресс" the Russian cargo spacecraft, или грузовои карабл (RS)
PRTD	Platinum Resistance Temperature Detector
PRV	Pressure Release Valve, клапан сброса давления
psia	pounds per square inch absolute pressure, фкнт на квадратный дюйм—палный
psid	pounds per square inch differential pressure, фкнт на квадратный дюйм—перепадый
psig	pounds per square inch gauge (absolute minus atmospheric pressure), фкнт на квадратный дюйм—имдикаций
PSU	Pressure Sensor Unit (Elektron) (RS)
Pt/Co	platinum/cobalt method of determining the true color of water; water quality parameter
PTCS	Passive Thermal Control System (RS)
PTO	A component of the Elektron (RS)
PU	pump unit
PVG	Pressure-Vacuum Gauge to check the pressure integrity of the docking seals through the TPTV (RS)
PWC	Potable Water Containers, Контейнер Питьевой Воды (КПВ)
PWS	Pressure Warning Sensor (RS)
PWT	Potable Water Tank (RS)
Q	quantity
QD	Quick Disconnect, fluid line connectors (USOS)
R	Review; verification method records
R&R	Removal and Replacement
RAM	Random Access Memory for computers, оперативное запоминающее устройство (ОЗУ)
RCA	Remote Control Assembly (MPLM)
RH	Relative Humidity, влажность
RM	Research Module, мсследовательский модуль (ИМ) (RS)
RMI	Rodnik Monitoring Indicator, индикатор контроля Родника (RS)
RMS	Remote Manipulator System (robotic arm) (JEM)
RPCM	Remote Power Control Module
RPDA	Remote Power Distribution Assembly
rpm	revolutions per minute rotational rate
RS	Russian Segment of *ISS*, российский сегмент МКС (РС)
RSA	Russian Space Agency, Российское Космическое Агентсво (РКА)
RTD	Resistance Temperature Detector
RU	A component of the Elektron (RS)
S	Similarity (verification method)
S	Siemens, metric unit of electrical conductivity (Cm in Russian)
SAE	Society of Automotive Engineers
safety	безоласность
Salyut	First series of Russian/Soviet Union space stations, Салют
scc	standard cubic centimeters
sccm	standard cubic centimeters per minute, кубческий сантиметр в минуту
SCFM, scfm	standard cubic feet per minute, кубических футов в минуту
SD	Sanitary Device (commode, Комод) (RS)
SDS	Sample Delivery Subsystem (USOS)
sec	second(s), unit of time, секунда (с)
SFOG	Solid-Fuel Oxygen Generator; expendable source of oxygen; Твердопливный Генератор Кислорода (ТГК) (RS)
Si gel	silica gel desiccant, влагопоглотитель
SHC	Shower Chamber (RS)

SHE	Sanitary-Hygienic Equipment (RS)
SHF	Sanitary/Hygienic Facility
SHW	Sanitary-Hygienic Water (RS)
SHWRS	Sanitary-Hygienic Water Recovery Subsystem (RS)
SKT–2	Activated charcoal in the HIF (RS)
SLWR	Solid and Liquid Waste Receptacle (part of the commode/urinal) (RS)
SM	The Russian Service Module, Служебный Модщль (RS)
SMAC	Spacecraft Maximum Allowable Concentration of atmospheric contaminants, предельно–допустимые концентрации (пдк), максималъно додустимая концентрация вешеств, содержащихся в атмосфере кабины космического аппарата
SMC	Systems Monitoring Console (on the *Mir*)
S/O	Standoff (USOS, APM, JEM, MPLM)
SO_4^{2-}	Sulfate
SOG	Solid-fuel Oxygen Generator (see SFOG)
SOS	Solid Oxygen Source; cassettes of perchlorates that are burned in the SFOG (RS)
Soyuz	Russian crew transfer vehicle, Корабль "Союз"
SPA	Solid Phase Acidification (in the U.S. water quality monitor)
space shuttle	In this document, the orbiter portion of the U.S. STS; strictly speaking, the space shuttle includes the main engines, external tank, and solid rocket boosters with the orbiter
SPOPT	part of FDS (RS)
SPP	Science Power Platform (RS)
SPSC	Systems Power Supply Console (RS)
SSP	Space Station Program document designation (e.g., SSP 42121)
SSRS	Space Suit Refilling System (RS)
stbd	starboard direction; right-hand side when facing forward, щтирборд
STP	Standard Temperature and Pressure
STS	Space Transportation System, Space Shuttle (US)
SU	Sensor Unit (RS)
suppress.	suppression
SV	space vacuum
SWC	Solid Waste Container
SWR	Solid Waste Receptacle, контейнер твердых отходов (КТО), (RS)
SWR–C	See CWRS
SWT	Service Water Tank, 210 L (RS)
T	test; verification method
tank	баллон
TBD	to be determined
TCCS	Trace Contaminant Control Subsystem, Блок очистки от микропримесей (БМП) или система удаления вредных примесей
TCCV	Temperature Control and Check Valve (U.S.)
TCS	Thermal Control System, система терморегулирования или система термоконтроля (СТ)
TEAC	Trace Contaminant Vent (RS), cassettes
technical water	Clean water treated with Ag^+ biocide (RS)
temp	temperature
TGS	Trace Gas Sample
TGSL	Trace Gas Sample Line
THC	Temperature and Humidity Control, ергуирование температуры и влажности (USOS) или система тепмовлагорерулирования, thermal-humidity control system
TIC	Total Inorganic Carbon
TIM	Technical Interchange Meeting
TMCS	Temperature Mode Control System (RS)
TOC	Total Organic Carbon, общее количество органического углерода (в воде)
TON	Threshold Odor Number (water quality parameter), вкус при 20 °C

total hardness	A measure of water quality (mg-eq/L), жесткость обшая (МГ–ЭКВ/Л)
TPTV	Tunnel Pressure Test Valves (RS)
TTN	Threshold Taste Number; water quality parameter; ,кус при 20 °C
TWC	Technical Water Container (RS)
UDM	Universal Docking Module, универсальный стыковочный модуль (RS)
UPA	Urine Processor Assembly
UR	Urine Receptacle, М-приемник (М-Пр), (RS)
U.S.	United States of America, Соединенные Штаты Америки (США)
USGS	U.S. Ground Segment of the *ISS*
USOS	U.S. On-Orbit Segment of the *ISS*, американский сегмент (АС)
UTOC	uncharacterized TOC
UWRCP	Urine Water Recovery Control Panel (RS)
UWRS	Urine Water Recovery Sub-system, система выделения воды из урины (RS)
V	volt(s), вольт
vacuum	вакуум
vacuum resource	A vent to provide space vacuum to experiments
VAJ	Vacuum Access Jumper
VCDS	Vapor Compression and Distillation Subassembly for processing urine, система регенерации воды на основе парокомпрессионной стилляции
ventilation	циркуляция атмосферы или вентеляция
venting	выброс за борт (удаление)
VES	Vacuum Exhaust Subsystem (USOS)
vestibule	The space between hatches of connected modules
vestibule jumper	A duct or hose that connects fluid lines between modules through the vestibule
VG	vacuum gauge
VOA	Volatile Organic Analyzer (USOS)
VOC	Volatile Organic Compounds
Vozdukh	Воздук, CO_2 removal assembly (RS)
VRA	Volatile Removal Assembly; for water purification, блок удаления летучих веществ для очистки воды
VRCV	Vent and Relief Control Valve (USOS)
VRS	Vacuum Resource Subsystem (USOS)
VRIV	Vent and Relief Isolation Valve (USOS)
VRV	Vent and Relief Valve, дренажный клапан (USOS)
VS	Vacuum Services, система вакуум (USOS, APM, JEM)
W	Watt, Ватт
WA	Water Accumulator (RS)
WSA–E	Water Supply Aids—Elektron
WSA–WS	Water Supply Aids—Water Supply
waste gas exhaust	Vent to dispose of waste gases to space
water	вода
water tank	бак дпя йранения воды
WCU	Water Conditioning Unit (RS)
WCUCA	WCU Columns Assembly (RS)
WCUCU	WCU Column Unit
WM	Waste Management, удаления отходов
WMC	Waste Management Compartment; commode (RS and USOS)
WMS–8A	Waste Management Subsystem–8A (RS)
W/O	without
WP	Water Processor, система регенерации питьевой воды (USOS)
WPCP	Water Procedure Control Panel (RS)
WPP	Water Pump Package (MPLM)
WR	Potable Water Reserves; storage tanks
WRM	Water Recovery and Management, регенерация и распределение воды

WRS–C	See CWRS (Water Recovery Subsystem—Condensate) (RS)
WRS–SH	See SHWRS (Water Recovery Subsystem—Sanitary/Hygienic Water) (RS)
WRS–U	See UWRS (Water Recovery Subsystem—Urine) (RS)
WSA–E	Water Supply Aids—Elektron (RS)
WSA–U	Water Supply Aids—Urine (RS)
WSA–WR	Water Supply Aids—Water Reserves (RS)
WSA–WS	Water Supply Aids—Water Supply (RS)
WSD	Water Supply Devices (RS)
WSF–SW	water dispenser, on the *Mir*
WT	Water Tank (едв, soft tank, etc.) (RS)
wt	weight
XFMR	transformer
ZAU	Zero Adjustment Unit, of the leak detection system (RS)
zen or z	zenith; direction, vertically overhead; зенит
zeolite	Molecular sieve material for CO_2 adsorption (5A) and as a desiccant (13X), цеолит, молекулярное сито или влагопоглотитель
4BMS	Four-Bed Molecular Sieve; CO_2 removal device; четыре патрона с цеолитом (молекулярными ситами) концентратор углекислого газа (USOS)
µg/L	Micrograms per Liter
µS/cm	microSiemans per centimeter; measure of electrical conductivity; measure of water quality; электропроводность (мкСм/см)
ΔP	"delta P," pressure differential дифференциальное (избыточное) давление, разность (перепад) давлений
Δt	change in time
$\partial P/\partial t$ or dP/dt	rate of change in pressure, Дельта давления/дельта времени

Russian Acronyms

АВН	emergency air leakage sensor
АСУ	Waste Management System
АСУ–СПК–У	Waste Management System with urine collection and preservation devices
АВК	emergency vacuum valve
БА	automatics unit
ББ	Core Module
БВ	water tank
БКГА	Gas Analyzers monitoring unit
БКО	water purification columns unit
БМП	*microimpurities removal unit*
БОА	atmospheric purification unit
БП	pumping unit
БПНУ	Zero Adjustment Unit
БРП	Distribution and Heating Unit
БСК	Condensate Separation Unit
В	fan
ГА	Gas Analyzer
ЕДВ	water container
ИПЖ	Liquid Leak Indicator
ИКР	Rodnik monitoring unit
ИП	indicator instrument
КБД	pressure equalization valve
КСОЖ	Environmental Control and Life Support System
КПВ	potable water container
КТВ	technical water container
КТО	solid waste container
МП	urine receptacle
ПАПС	Caution and Warning Panel
ПКП	parameters monitoring console
ПКС	systems monitoring console

ПСМ	module systems console
ПТЖО	solid and liquid waste collector
ПУВП	water procedure control panel
ПУРВ–У	Urine water recovery control panel
ПУРВ–К	Condensate water recovery control panel
РЗК	hand-operated shutoff valve
РН	hand-operated pump
СВВ	water-air mixture
СБА	gas analysis devices
СЖО	Life Support System
СКО	oxygen supply devices
СОА	atmospheric purification devices
СОБС	Environmental Control System
СОТ	pressing-out collector
СРВ-СГ	sanitary-hygienic water recovery system
СРВ-У	Urine Water Recovery System
СТР	Thermal Control System
СУБК	Onboard Complex Control System
СГК	Solid-fuel Oxygen Generator
ШК	Airlock

TECHNICAL MEMORANDUM

LIVING TOGETHER IN SPACE: THE DESIGN AND OPERATION OF THE LIFE SUPPORT SYSTEMS ON THE *INTERNATIONAL SPACE STATION*

CHAPTER I: OVERVIEW

1.0 Introduction

The *International Space Station* (*ISS*) is an unsurpassed cooperative venture between the United States and international partners—which include the Canadian Space Agency (CSA), European Space Agency (ESA), Italian Space Agency (ASI), National Space Development Agency (NASDA)—and the Russian Space Agency (RSA). In order for the people who operate the equipment to be able to ensure optimal performance and to respond to off-nominal or emergency situations it is essential that the systems in each segment be well understood by all the partners. Compatibility between the systems must be assured during design and development. This is especially true for the Environmental Control and Life Support (ECLS) Systems (ECLSS). In addition, knowledge of the Russian ECLS technologies (developed through years of flight experience) can be of great value to US/international segments ECLSS designers, and knowledge of the US/international segments ECLS technologies can be of benefit to the Russian ECLSS designers.

For these reasons, this report describes the design, operation, and performance of the different ECLS systems developed for use on the *ISS*. This chapter includes a general description of the *ISS* and the different segments, the construction sequence and ECLS capabilities at significant phases of assembly, the specifications that the ECLS systems are designed to meet, the interface connections between the different ECLS systems, the requirements and design philosophies that affect the design of the different ECLS systems, and the quality assurance and reliability factors that affect the design process. The other two chapters provide more detailed information about each specific ECLSS and the technologies used. The Russian ECLSS is discussed in general in this chapter, and in more detail in Volume II (which has a restricted distribution).

1.1 Background

Russia has gained extensive experience with long duration human space flight since the first *Salyut* space station was launched in 1971. Almost continuous human presence in space was provided by a succession of *Salyut* stations during the following 2 decades, each having improvements over the previous ones. In 1986, a new generation of space stations became operational with the launch of the *Mir*, which was designed to have a longer life and to allow additional pressurized modules to be attached. Some Russian cosmonauts have lived in space continuously for more than 1 yr.

The U.S. experience with long duration human space flight is more limited, consisting of the *Skylab* program that culminated in three missions during 1973 and 1974 of 28, 59, and 84 days, respectively. Since *Skylab,* the longest duration U.S. missions have been 17 days, aboard the space shuttle. With the recent shuttle/*Mir* missions, as part of *ISS* Phase 1, American astronauts have lived aboard *Mir* for several months each.

As of September 1997, the overall configuration and assignment of responsibilities among the partners are changing. For example, Node 2 and Node 3 (in place of the U.S. Hab) are now the responsibility of Italy, and the centrifuge is now the responsibility of Japan. These changes, so far, have not included changes to the ECLS hardware. The ECLS functions and the techniques used to perform those functions are as described in this report.

The ECLS systems on the early *Salyut* stations were very similar and relatively simple, using nonregenerable techniques for most of the life support functions and relying on resupply of water and oxygen (O_2) (in the form of potassium superoxide which also absorbs carbon dioxide (CO_2), although lithium hydroxide (LiOH) was used to remove about 20 percent of the CO_2). With *Salyut 4*, a water recovery system was added to recover humidity condensate and waste hygiene water. With *Mir*, an O_2 generation assembly was added which electrolyzes water to produce O_2. Also on *Mir*, CO_2 is removed by a regenerable technique and vented to space. A device to recover O_2 from CO_2 has been developed but has not yet been used in space.

The ECLSS on *Skylab* included stored water and O_2, a regenerable molecular sieve for CO_2 and humidity removal (and venting to space), and fire detectors based on ultraviolet light detection. Trace contaminant removal was accomplished by depressurizing the habitat between missions, allowing the pressure to drop to 3.45 kPa (0.5 psia). The space shuttle uses nonregenerable methods for almost all ECLSS functions, although a regenerable CO_2 removal device is now being used and other methods of reducing expendables to increase the duration of missions are being developed.

1.2 *ISS* Mission Scenario

The *ISS* is designed as a low-Earth-orbit research laboratory and technology development facility for materials science, biological, medical, and related research. It also will serve as a platform for Earth and astronomical observations. The *ISS* is designed to have an operational life of at least 10 yr (the Russian Segment (RS) operational life is at least 15 yr after the first element is launched), with the capability for upgrading and replacing rack-mounted hardware.

The *ISS* project consists of three phases:

- Phase 1 is a series of missions by the U.S. space shuttle to the *Mir* as training for *ISS* assembly and operation.

- Phase 2 is assembly of the *ISS* to support a three-person crew.

- Phase 3 is completion of *ISS* assembly and provides for seven-person permanent habitation, mature operations, and full international science capabilities.

The normal crew size is 6 people, although during crew exchanges there may be as many as 12 people on board the *ISS*. The crew capacity is limited by CO_2 levels, not by humidity, O_2, or temperature levels. Crew exchanges occur at intervals of approximately 90 days. Supplies are delivered by a Progress cargo vehicle to the RS and by the Mini-Pressurized Logistics Module (MPLM) (five resupply missions each year) to the U.S. On-Orbit Segment (USOS) and the international segments. The internal operating environment is close to Earth-normal at sea level; the pressure is near 101.3 kPa (14.7 psia), and the atmosphere composition is approximately 79 percent nitrogen (N_2) and 21 percent O_2 (by volume for dry air).

During the construction period, the RS has the capability for waste processing and water purification before the U.S./international segments and for that period of time supports the entire *ISS* for those functions. Also during that period, the Russians provide O_2 and N_2 for metabolic consumption and leakage. The United States provides makeup gases for airlock (AL) losses.

2.0 Description of the *ISS* and the ECLS Systems

The *ISS* consists of modules and components being developed by a consortium of space agencies. The overall configuration is shown in figure 1. The *ISS* is separated into two major sections that are connected, but in many ways are independent: the U.S./international segments and the RS. The ECLSS for each section operates independently, as shown schematically in figures 2 and 3. These figures show the locations of the component ECLS subsystems. The segments and the sequence of assembly are described below. (The ECLS capabilities are listed in table 5 for each *ISS* element.)

General characteristics include:

- There are no automatic hatch open/close mechanisms on any U.S., Russian, or other international partner hatches.
- The fire suppression system is decentralized and consists of portable fire extinguishers (PFE).
- A single failure of equipment is not to propagate across the RS/USOS interfaces (defined in SSP 42121).
- Materials are selected so as to not contaminate the air; i.e., the materials have minimal offgassing.

The functions that U.S. designers typically consider part of the ECLSS are: Atmosphere Revitalization (AR), Water Recovery and Management (WRM), metabolic Waste Management (WM), Atmosphere Control and Supply (ACS), Temperature and Humidity Control (THC), and Fire Detection and Suppression (FDS). For the *ISS*, vacuum resources and exhaust for experiments are also considered part of the ECLSS.

The Russian ECLSS designers include food storage and preparation, refrigerators/freezers, extravehicular activity (EVA) support, whole body cleaning, and housekeeping as part of the ECLSS. These are generally considered part of "crew systems" by NASA and, except for EVA support, are not discussed in this report. Conversely, the Russians consider thermal control to be a separate system. Also, the Russians categorize the ECLS capabilities somewhat differently than U.S. ECLSS designers. For example, the Russian category translated as "sanitary and hygienic equipment" includes the commode, urinal, hand washers, vacuum cleaner, and thermal chamber (for whole body cleaning), whereas the U.S. category "waste management" includes the commode and urinal only.

2.1 Description of the Russian Segment and ECLS Capabilities

The RS provides guidance, navigation, and control; propulsion services; electrical power generation, storage, distribution, and control; communications and data links to ground support facilities; ECLS; thermal control and heat rejection; data processing, storage, and transportation; housekeeping; personal hygiene; food preparation and storage; EVA; support payload utilities; robotic systems; crew and cargo resupply services; delivery and return of crew, including unplanned crew return capability; and research facilities.

The RS consists of the following pressurized modules:

- A module to connect with the USOS and provide initial essential services—the functional cargo module (FGB, from the Russian name for the module)
- A habitation module for three people, nominally—the Service Module (SM)
- Laboratory modules—Research Modules RM1, RM2, and RM3
- A Life Support Module (LSM) that can support up to six people
- A Docking and Stowage Module (DSM)
- Logistics resupply modules (Progress, two versions, one with Rodnik tanks, the other without Rodnik tanks)
- Crew Transfer Vehicles (CTV) (also referred to as Assured Crew Return Vehicles (ACRV))
- A module for connecting the other modules—the Universal Docking Module (UDM)
- A module for docking another vehicle—the Docking Compartment (DC). The DC is also used as an ALwhen EVA's are performed
- Modules that connect the solar arrays and thermal radiators to the SM—the Scientific-Power Platforms (SPP–1 (pressurized) and SPP–2 (unpressurized)).

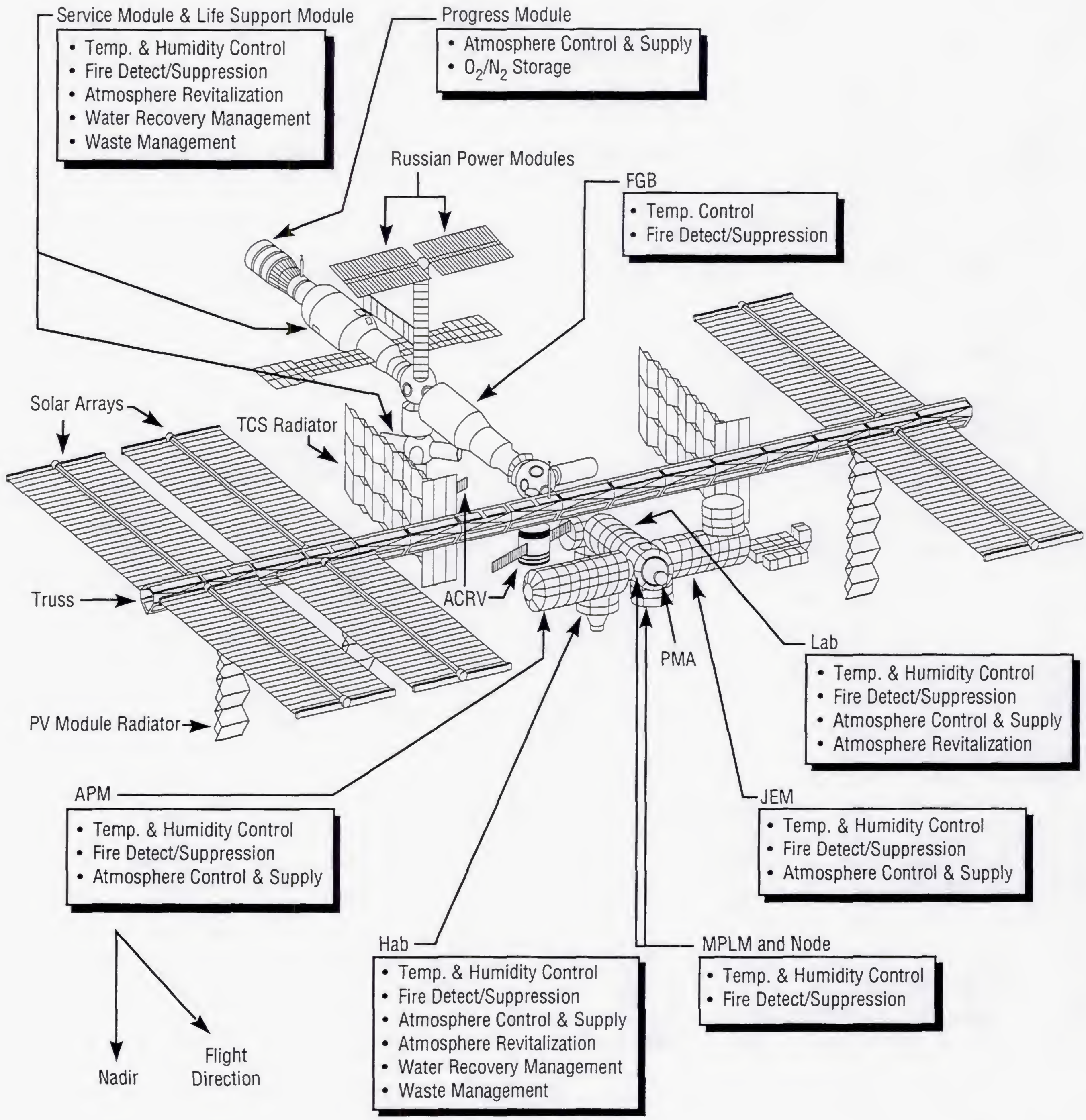


FIGURE 1.—*ISS* configuration.

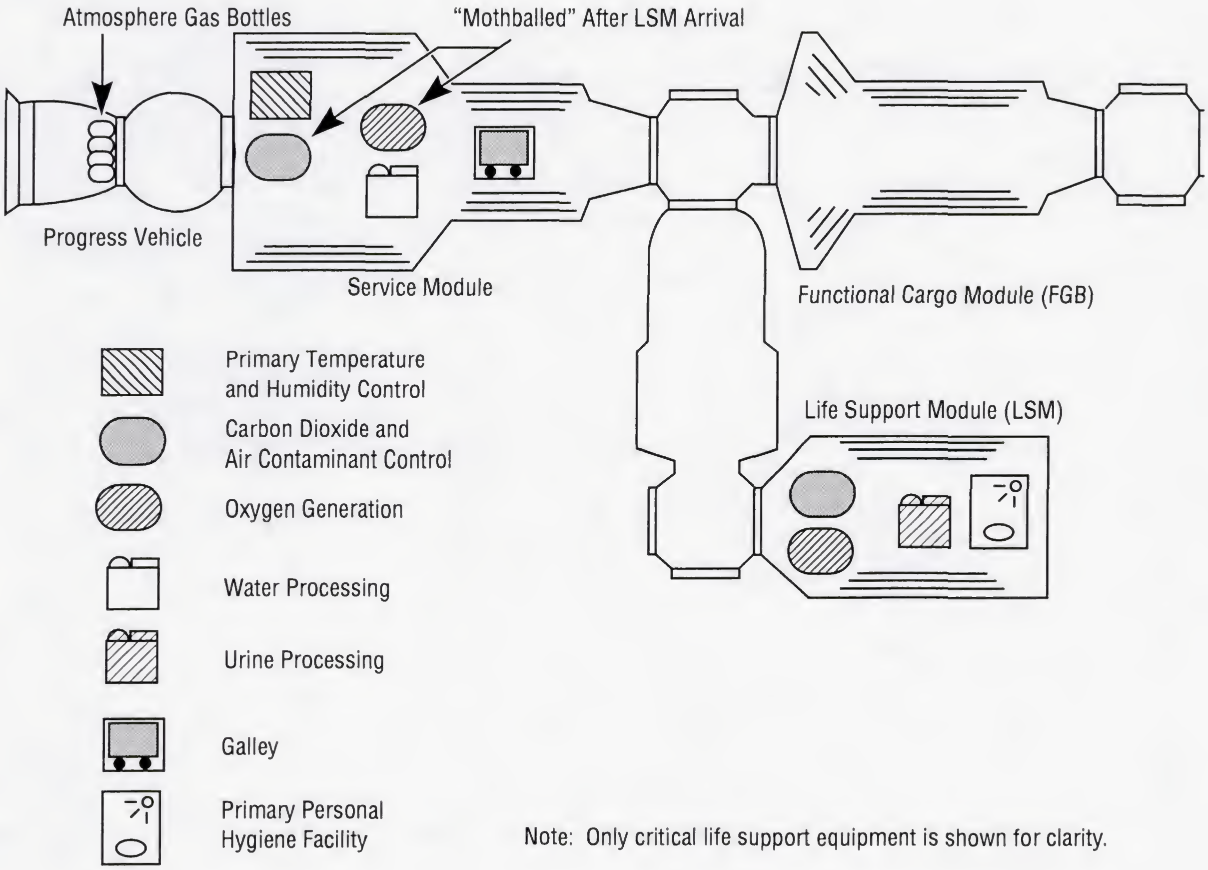
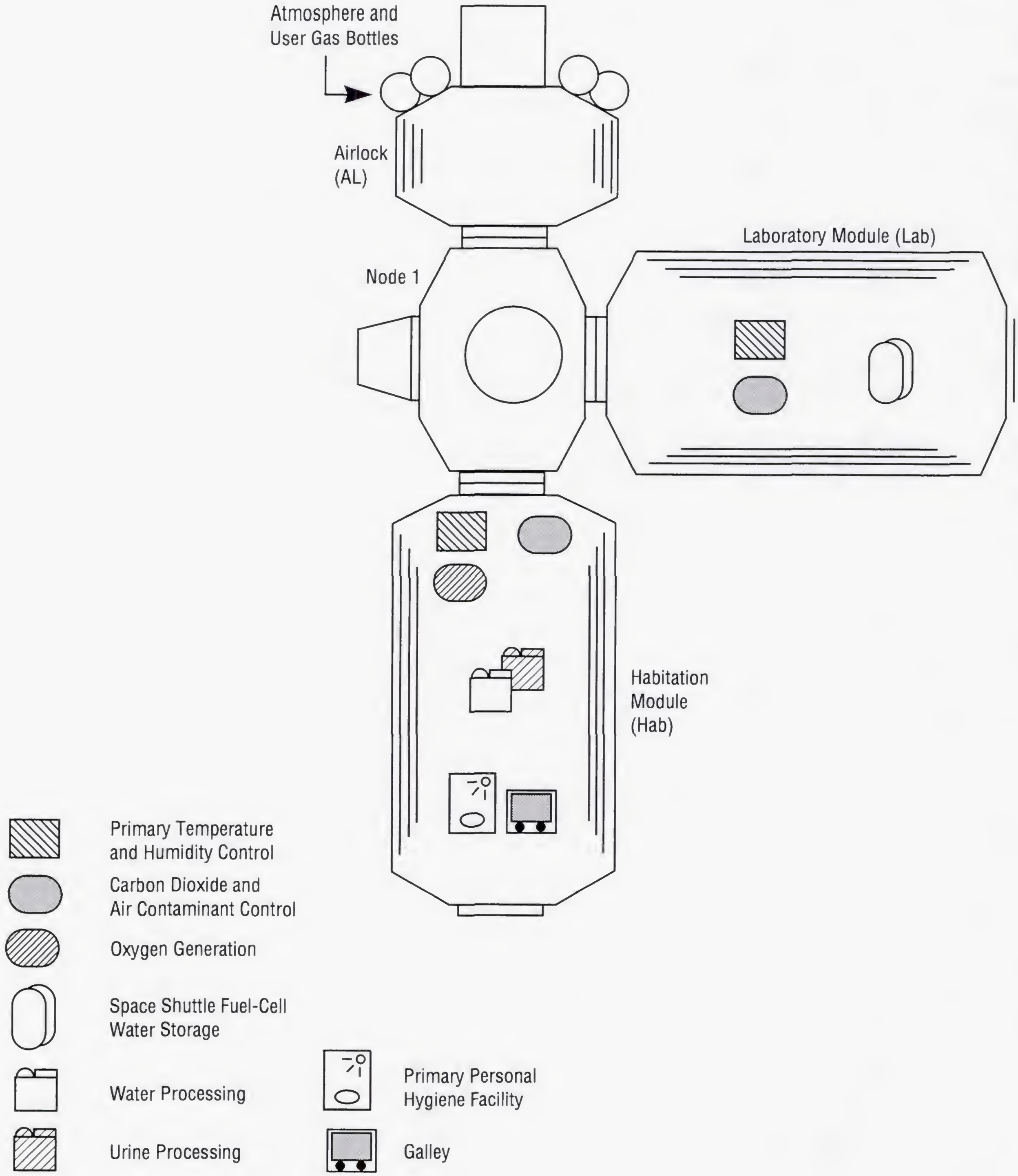


FIGURE 2.—RS ECLSS.



Note: Only critical life support equipment is shown for clarity.

FIGURE 3.—USOS ECLSS.

In addition, there are solar arrays, thermal radiators, propulsion equipment, and communications equipment.

These elements are installed over a period of 4 1/2 yr, beginning in 1998. The RS, as built, may have some differences from the description given here due to late changes in the configuration. For example, there may be a second LSM due to use of a smaller module than originally proposed. The types of ECLS equipment used are expected to be the same as described in this report.

The FGB, shown in figure 4, is the first element placed in position and provides the "foundation" for assembly of the other *ISS* elements. It also provides reboost and attitude control until the SM is activated. The FGB contains systems for propulsion; guidance, navigation, and control; communications; electrical power; partial life support functions; and thermal control. After the SM is activated, the FGB serves as a propellant storage facility. The ECLSS hardware in the FGB performs the functions of:

- ACS, using a gas analyzer for atmosphere composition monitoring (to monitor the partial pressures of O_2 (ppO_2) and CO_2 ($ppCO_2$) and relative humidity), total pressure sensors, a pressure gauge, and pressure equalization valves between compartments that can be actuated either remotely by the ground or manually by the crew.

- Temperature control, using fans and heat exchangers.

- FDS, using smoke detectors, PFE, Portable Breathing Apparatus (PBA) (face masks), and a fire indicator panel.

- Trace contaminant removal from the atmosphere, using air cleaners (i.e., charcoal filters) that remove hazardous gases and dust filters (two in the FGB).

The FGB operates in two modes: (1) unoccupied, in which pressure monitoring and ventilation occurs continuously, and (2) docked to the SM. In the unoccupied mode, O_2 and CO_2 levels are monitored periodically. When docked to the SM, the FGB relies on the SM for maintaining the atmospheric quality. The FGB provides the motive force (blowers) for intermodule ventilation to the USOS. The flowrate from the SM to the USOS is 70 L/sec (148 cfm) at 1 to 2 mm H_2O (0.04 to 0.08 in H_2O) pressure head. Prior to activation of the U.S. Hab, the FGB receives air from the USOS that is slightly low in O_2 and may have some particulates and trace gases. (The USOS has a trace gas monitor operating in the U.S. Lab, i.e., the Crew Health Care System's (CHeCS) Volatile Organic Analyzer (VOA), and a Carbon Dioxide Removal Assembly (CDRA) and Trace Contaminant Control Subassembly (TCCS) to remove CO_2 and trace contaminants.)

The largest module is the SM, shown in figure 5, with a pressurized compartment that is 13.1 m (43.0 ft) in length by 4.1 m (13.5 ft) internal diameter, with a total mass of 23,000.0 kg (50,660.8 lb), 2,323.0 kg (5,116.7 lb) of which is the life support system. The SM serves as the structural and functional center of the RS, providing living and working space and supporting communications, research, and experiments. The SM is the primary RS element for propulsion; guidance, navigation, and control; and communications. The SM also provides initial life support capability for up to six people, and backup life support capability after the activation of the LSM. The ECLSS hardware in the SM performs the functions of:

- ACS, using a gas analyzer for atmospheric composition monitoring (to monitor ppO_2, $ppCO_2$, and relative humidity), total pressure sensors, a pressure gauge, and pressure equalization valves between compartments that can be actuated either remotely by the ground or manually by the crew. The SM also provides for introducing O_2 into the atmosphere and detecting rapid decompression.

- THC, using fans and condensing heat exchangers (CHX) to remove excess moisture from the atmosphere.

- Water storage and distribution to provide water for potable and hygiene use, and collection and storage of wastewater for disposal. Condensate water collected from the CHX's is processed to potable-quality water. Two Rodnik service water tanks are mounted in the Assembly Compartment (AC) outside of the pressurized compartment of the SM.

- AR by removing CO_2, using LiOH or regenerable CO_2 sorbents; removing gaseous contaminants, using a low-temperature catalytic oxidizer; and removing airborne particles and microorganisms, using filters. Carbon monoxide (CO) detection is also considered to be an AR function.

- WM, using a commode to collect and dispose of crew metabolic waste.

- EVA support by providing O_2 and other ECLS services.

- FDS, using smoke detectors, PFE's, PBA's, and a fire indicator panel. The master fire panel is also located in the SM.

The SM also provides backup EVA capability through the node (or "ball area") which serves as an AL prior to installation of the DC.

The LSM is 8.2 m (27.0 ft) in length by 2.9 m (9.5 ft) in diameter. It supplies life support functions that complement those of the USOS capabilities and the SM, and provides a greater degree of mass loop closure by recovering useful products from waste products.

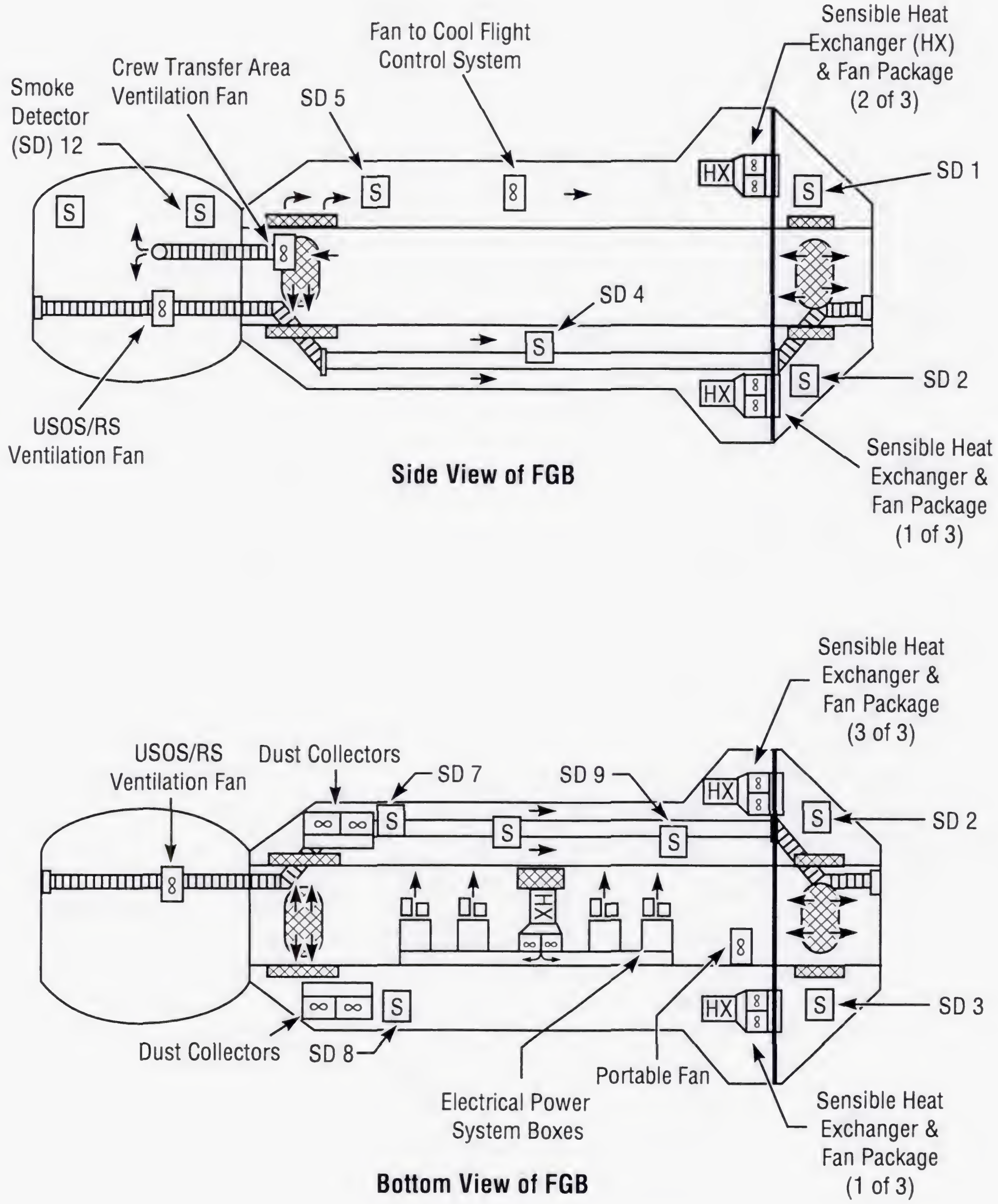


FIGURE 4.—FGB equipment locations.

The ECLS functions in the LSM consist of O_2 supply, CO_2 removal and reduction, trace contaminant control, atmospheric composition monitoring, water supply from storage and water recovery from urine, and a thermal chamber for whole body cleaning. The LSM has two observation windows.

The DSM provides a location to store potable water, spare parts, and other supplies.

The RM's provide facilities for science experiments and materials processing. The ECLS functions consist of atmospheric pressure measurement, contaminant removal, temperature measurement and control, atmospheric circulation, intermodule ventilation, and FDS.

The Universal Docking Module (UDM) provides ports for attaching the RM's, the LSM, and the DC. The ECLS functions consist of atmospheric pressure measurement, contaminant removal, temperature measurement and control, atmospheric circulation, and intermodule ventilation. Also, the pump used to evacuate the AL and other EVA support capabilities are provided in the UDM, which also has a ball area that serves as an AL prior to installation of the DC.

The CTV is a Soyuz vehicle, a self-contained spacecraft equipped with basic life support sufficient for short duration transfers between Earth and low-Earth orbit; propulsion; guidance, navigation, and control; and communications capability. The ECLS capabilities include atmospheric pressure measurement and intermodule ventilation.

The DC provides a port for docking and serves as an AL for EVA operations. The ECLS functions consist of atmospheric pressure measurement, contaminant removal, temperature measurement and control, atmospheric circulation, and intermodule ventilation. Also, EVA aids and the valve for evacuating the AL are located in the DC.

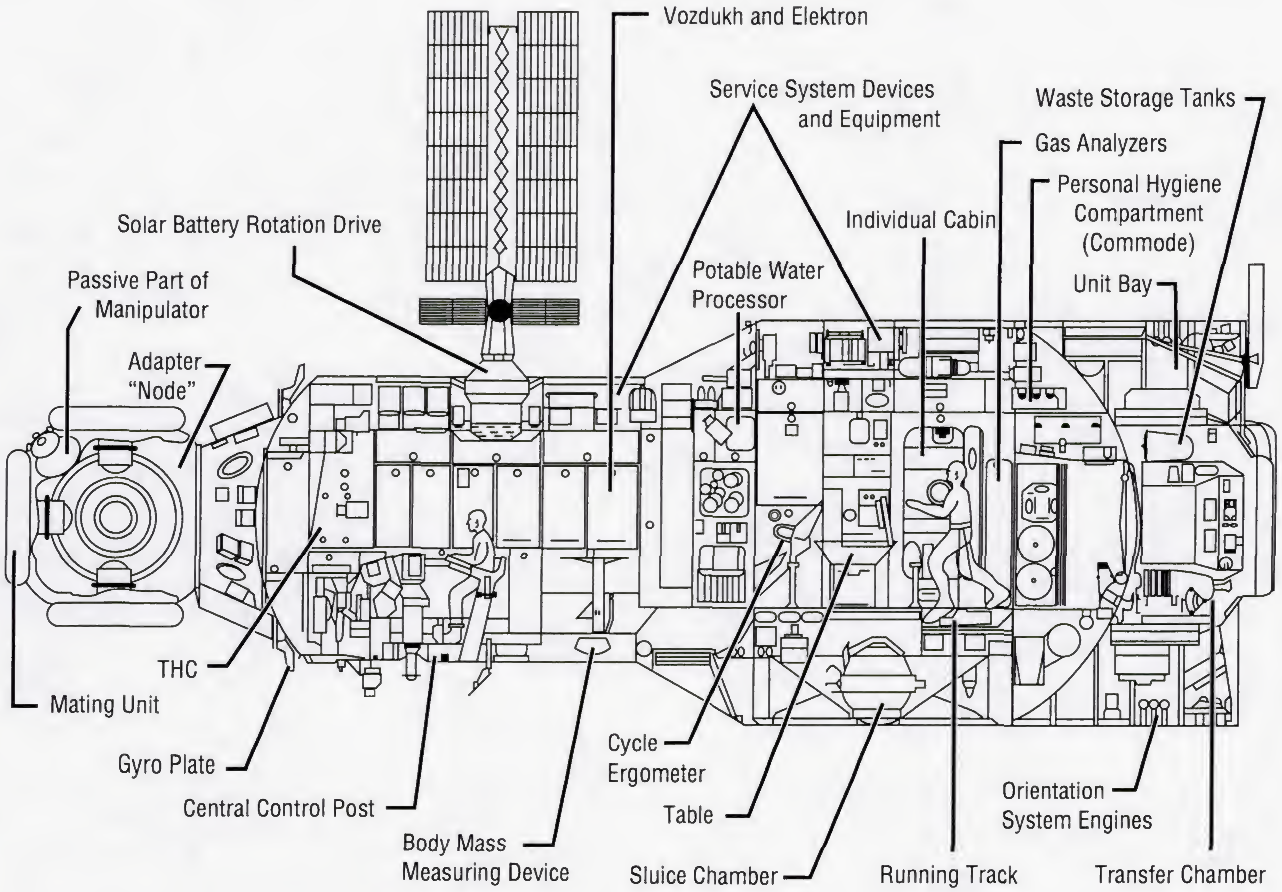


FIGURE 5.—RS service module equipment locations.

The SPP–1 provides a pressurized volume for access to the power supply and heat rejection systems. The ECLS functions consist of atmospheric pressure measurement, contaminant removal, temperature measurement and control, atmospheric circulation, and intermodule ventilation.

The Progress is a cargo vehicle for resupplying dry cargo, water, propellant, and atmospheric gases. It also provides reboost capability. The vehicle is 7.23 m (23.7 ft) in length by 2.5 m (8.2 ft) in diameter. It serves as a carrier of expendable items (such as fluids, filters, and food) and equipment (such as scientific experiments). The Progress ECLSS hardware performs the functions of:

- Atmospheric supply using tanks for storage of resupplied atmosphere gases, controlled release of those gases, and a total pressure sensor to monitor atmospheric pressure.
- Atmospheric temperature monitoring and intermodule ventilation.
- Water supply and management using tanks for storage and delivery of potable water and disposal of wastewater.

Some U.S.-provided equipment for monitoring the environment is used on the RS. This equipment includes:

- Charged particle directional spectrometer
- Tissue equivalent proportional counter
- Radiation area monitors
- Surface sampler kit
- Microbial air sampler
- Fungal spore sampler
- Compound specific analyzer for combustion products
- Water microbiology kit
- Water sampler and archiver
- Crew contamination protection kit.

2.2 Description of the U.S. On-Orbit Segment and ECLS Capabilities

The USOS provides living quarters for three people; electrical power generation, storage, distribution, and control; communications and data links to ground support facilities; environmental control and life support; thermal control and heat rejection; data processing, storage, and transfer; housekeeping; personal hygiene; food preparation and storage; EVA capability; payload utilities; robotic systems; crew and cargo resupply services; and research facilities.

The USOS consists of the following pressurized modules:

- A laboratory module—the Lab
- A habitation module for three people, nominally—the Hab
- Two nodes for connecting the U.S. and international modules—Nodes 1 and 2
- An AL
- Three pressurized mating adapters (PMA)
- A cupola with windows for viewing external operations, including EVA's and use of the robotic arm
- A centrifuge module (planned, but not yet defined).

In addition, there are trusses, solar arrays, thermal radiators, and communications equipment.

The Lab is about 4.4 m (14.5 ft) in diameter (sized to fit in the cargo bay of the space shuttle) and 7.3 m (24.0 ft) in internal length plus the end cones (total length is about 8.4 m (27.5 ft)). The Lab provides a facility for scientific research and commercial applications. The Lab is designed to accommodate equipment that is packaged in standard "racks"—International Standard Payload Racks (ISPR) that are interchangeable—and contains locations for 24 racks including equipment racks for essential services such as ECLS, as well as payload racks.

The ECLS functions included in the Lab are: ACS, THC, AR, FDS, water for payloads, and vacuum service and gases (N_2) for payloads. The interior of the Lab is designed to have an "up" and "down" orientation. ISPR's are located on each "wall," the "floor," and the "ceiling." This is shown in figure 6, a cutaway view of the Lab interior. The Lab has one 0.51 mm (20 in) diameter window.

The Hab is the same size as the Lab and provides living quarters for the crew, including sleeping accommodations, a galley, recreation facilities, crew health care, and hygiene facilities. The Hab is also designed to accommodate equipment packaged in ISPR's. The ECLS functions included in the Hab are: ACS, THC, AR, FDS,

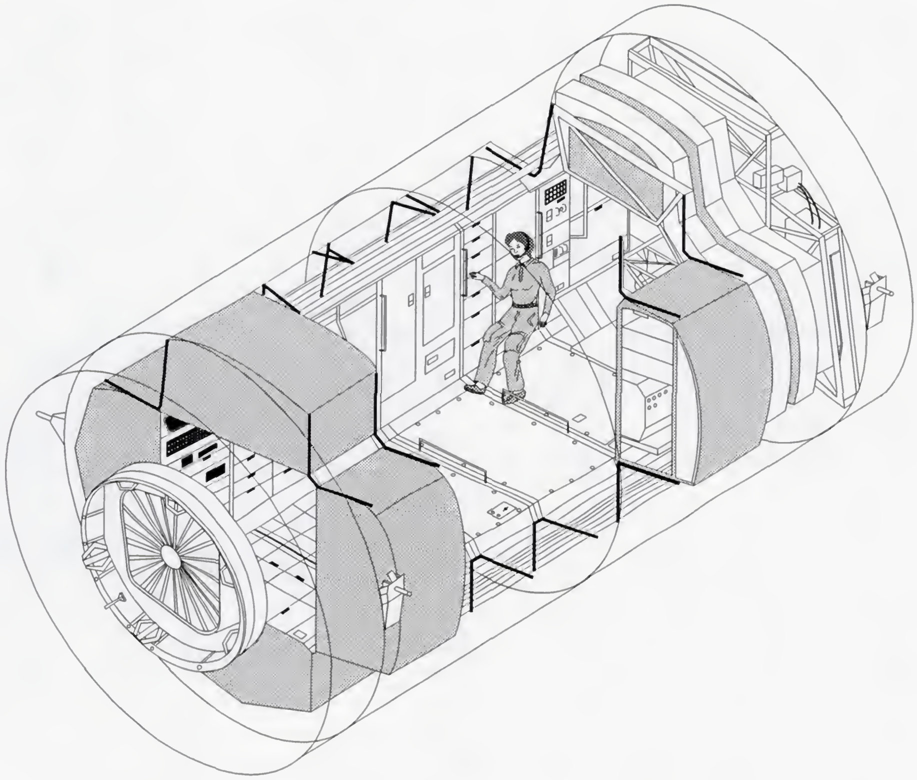


Figure 6.—Isometric cutaway view of the U.S. Lab ("*ISS* Reference Guide," 15 March 1994).

WM, and WRM. The interior of the Hab is also designed to have an "up" and "down" orientation. The Hab has two windows.

The nodes are the same diameter as the Lab and Hab but are about 3 m (10 ft) shorter (i.e., 5.5 m (18 ft) in length). The node exterior and interior design is shown in figure 7. There are four radial ports and two axial ports for attaching modules or a PMA. A cupola is attached to Node 1 so that external operations, including use of the robotic arm, can be observed and/or controlled from inside the *ISS*. Node 1 also serves as a storage location and contains only a limited amount of powered hardware for its own operation. Cables and plumbing from other modules are connected through Node 1. The ECLS functions consist of intermodule ventilation, intramodule atmosphere circulation, pressure equalization, total atmosphere pressure monitoring, FDS, and atmospheric filtration. Node 2, in addition, contains equipment for primary-to-secondary power conversion, and has THC capability, including a CHX. Neither Node 1 nor Node 2 has the capability to respond to rapid decompression.

The PMA's are connectors between the USOS docking ports and a space shuttle, and between the USOS and the FGB. The PMA's are environmentally controlled to accommodate the passage of people and equipment, and the transfer of utilities. PMA–1, shown in figure 8, has a duct for inter-module ventilation (IMV). ECLS in PMA–2 and –3 includes pressure equalization capability and plumbing to transfer fuel-cell water from a space shuttle.

The joint AL, shown in figure 9, provides the capability for EVA's; i.e., depressurization, egress, ingress, and repressurization. The AL contains the equipment to perform external operations and consists of two cylindrical chambers attached end-to-end by a connecting bulkhead. The larger chamber is the equipment lock and the smaller chamber is the crew lock. As shown in figure 10, the equipment lock contains the pressure suits (Extravehicular Mobility Units (EMU)), maneuvering units, and support equipment necessary to perform an EVA. The equipment lock is used for equipment storage and transfer, and preparing for EVA missions. The crew lock is used for egress and ingress of

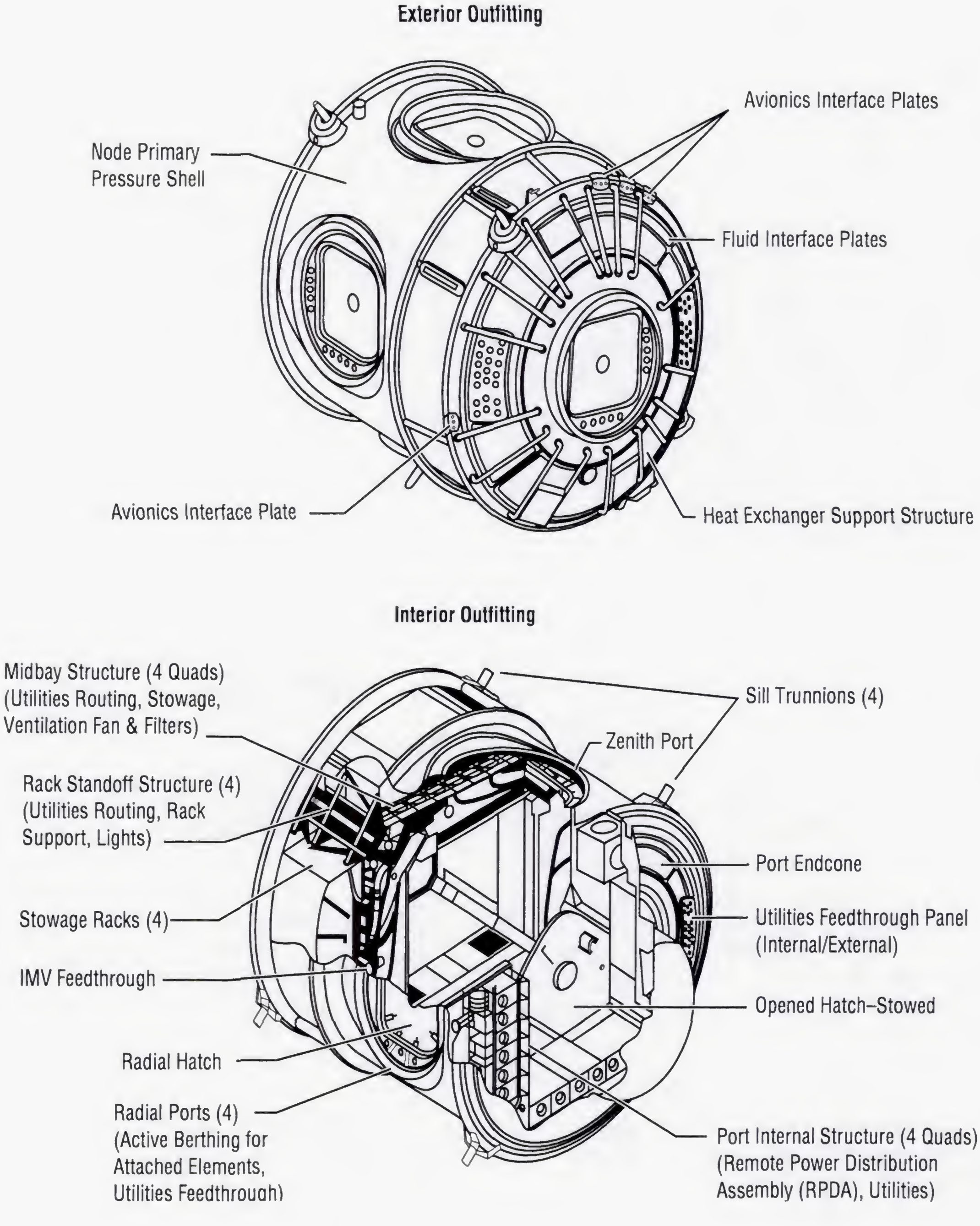


Figure 7.—Nodes 1 and 2 design and outfitting ("*ISS* Reference Guide," 15 March 1994).

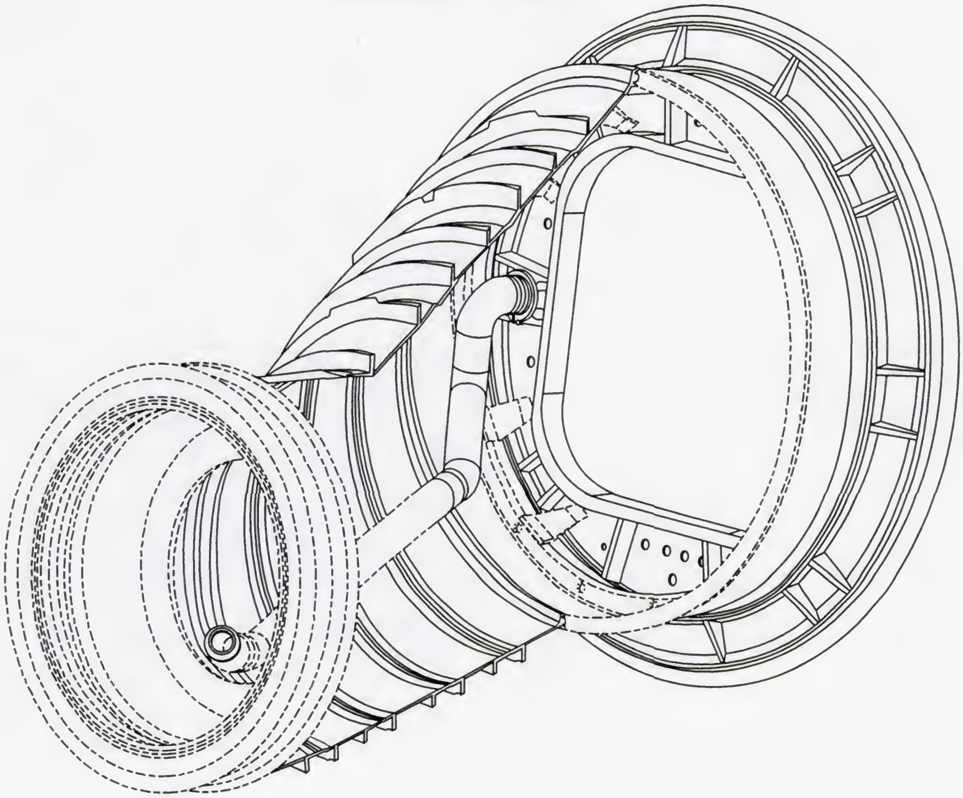


FIGURE 8.—PMA-1.

suited crew members and for transfer of equipment to and from space. It is also used for storing equipment to be transferred to or from space and provides a location to prepare for EVA missions.

In operation, the pressure in both AL chambers is reduced to 70.33 kPa (10.2 psia) during the "campout" period prior to an EVA. This allows the N_2 level in the EVA crew members' blood to be safely reduced prior to use of the EMU pressure suits, which operate at 29.63 kPa (4.3 psia). To exit the *ISS*, the atmosphere in the crew lock is pumped to Node 1. The equipment lock is repressurized to 101.3 kPa (14.7 psia) by opening the Manual Pressure Equalization Valve (MPEV) between the equipment lock and Node 1 (there is no hatch on the AL side). The ECLS functions support preparation for, performance of, and recovery from EVA's, and consist of ACS, THC, some AR, FDS, stored potable water supply, and EVA support. Potable water is brought to the AL, as needed, to recharge the EMU's.

The cupola is a controlling workstation that provides full hemisphere viewing for monitoring the Earth, celestial objects, exterior *ISS* surfaces, space shuttle docking, and EVA's. The cupola is attached to Node 1, which provides the necessary ECLS functions. No special ECLS functions are performed in the cupola.

The centrifuge, attached to Node 2, provides a variable "gravity" (G) facility for scientific experiments, primarily biological research. The centrifuge is 2.5 m (8.2 ft) in diameter with four habitats to support plants and animals in different gravitational environments, from 0.01 to 2 G. The ECLS functions consist of pressure equalization capability and FDS. (Details are not presently available.)

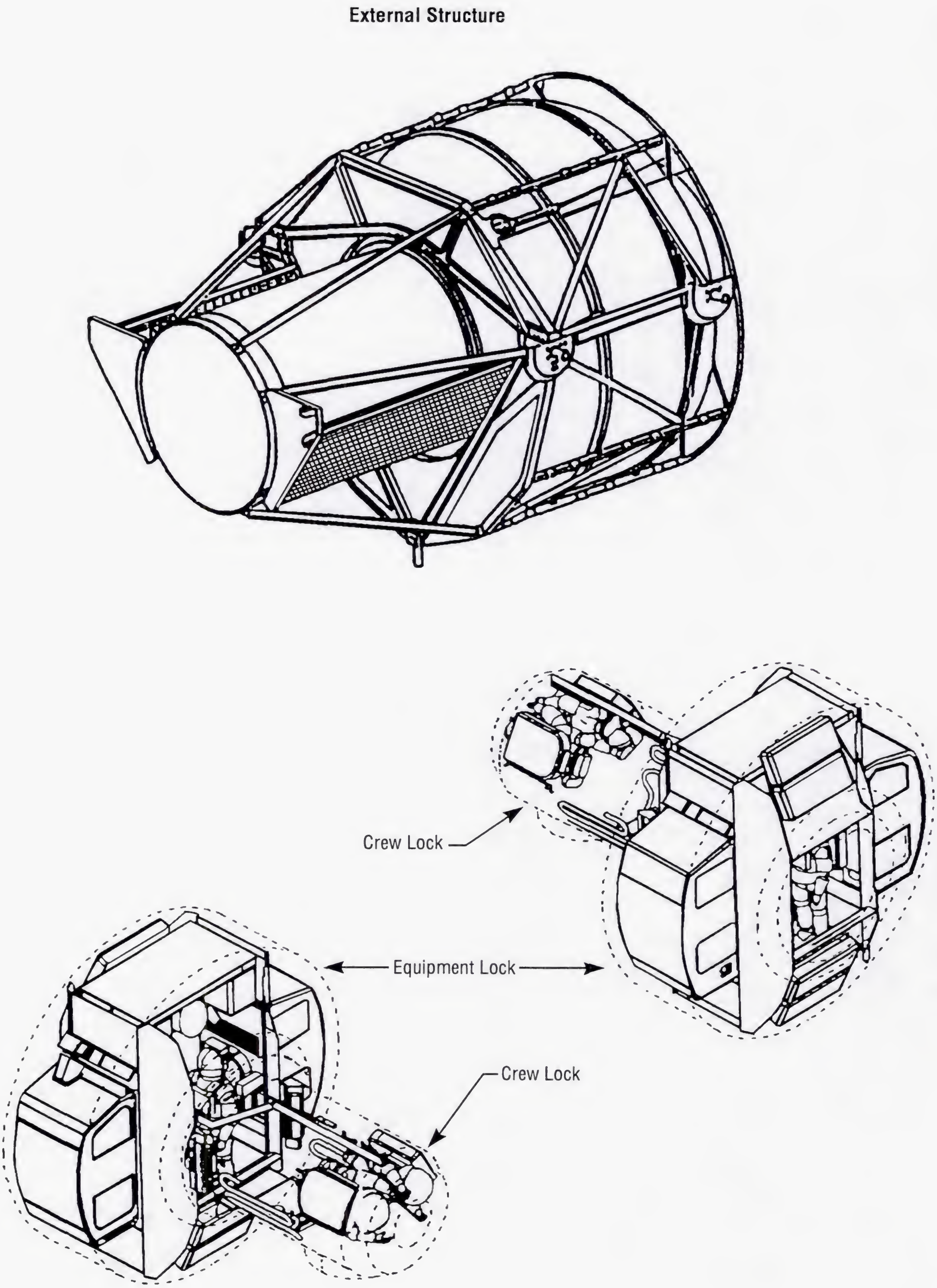


FIGURE 9.—Joint AL.

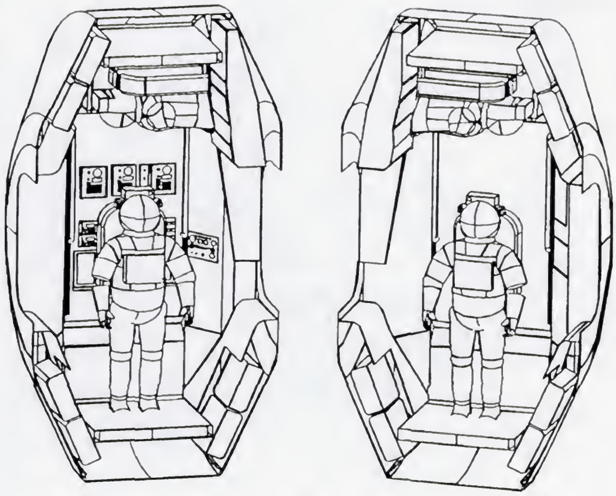


Figure 10.—Joint AL equipment lock.

2.3 Description of the International Segments and ECLS Capabilities

The international segments consist of:

- The Attached Pressurized Module (APM) provided by ESA.
- The JEM with a Pressurized Module (PM), an Exposed Facility (EF), an Experiment Logistics Module-Pressurized Section (ELM–PS), and an Experiment Logistics Module-Exposed Section (ELM–ES) provided by NASDA.
- The MPLM provided by ASI.

The JEM and MPLM are shown in figures 11 and 12, respectively. The APM is similar in appearance to the US Lab (fig. 6).

The APM (approximately 6.7 m (22.0 ft) in length and 4.4 m (14.5 ft) in diameter) and the JEM (9.9 m (32.5 ft) in length and 4.2 m (13.8 ft) in diameter for the PM, and 4.1 m (13.5 ft) in length and 4.2 m (13.8 ft) in diameter for the ELM–PS) provide laboratory facilities for scientific experiments and research, with internally-mounted ISPR's and externally-mounted pallets exposed to the space vacuum. The MPLM (6.7 m (21.9 ft) in length and 4.5 m (14.7 ft) in diameter) is a cargo module for transporting supplies and replacement ISPR's to the *ISS* and for returning ISPR's, waste products, and manufactured products to Earth. The cargo can either be passive only, or include cold cargo in refrigerators/ freezers.

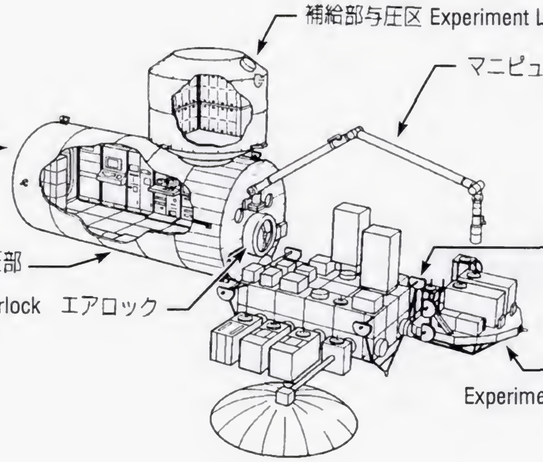
The APM, JEM, and MPLM have ventilation ducting and limited FDS capability, but primarily depend on the U.S. Lab for the ECLS functions. The ECLSS functions and features that are common to the APM, JEM, and MPLM include:

- **Atmosphere Control and Supply (ACS)**
  - Depressurization, vent, and relief
  - Repressurization, pressure equalization
  - Positive pressure relief
  - Negative pressure relief
  - Total pressure monitoring and control
- **Atmosphere Revitalization (AR)**
  - Collection and delivery to the USOS of atmosphere samples for analysis
  - Responding to hazardous atmosphere.
- **Fire Detection and Suppression (FDS)**
  - Smoke detection in the potential fire source locations
  - Determining a fire location after its detection
  - Fire suppression using a PFE.
- **Temperature and Humidity Control (THC)**
  - Atmospheric circulation for crew comfort and to ensure detection of fires
  - IMV connection with the USOS
  - Atmospheric temperature monitoring

ECLS functions that are present in the APM and JEM (but not in the MPLM) are vacuum services, supply gases (gaseous N_2) to payloads, atmospheric humidity control, and control of airborne particulates and microorganisms. Radiation exposure monitoring is provided by the USOS CHeCS.

JEM 初期段階構成図

JEM Baseline Configuration



参加が考えられる主な利用テーマ

コード	ミッション・テーマ名	コード	ミッション・テーマ名
M–1	材料基礎科学実験	L–4	バイオテクノロジー
M–2	新材料製造実験	S–3	高エネルギー宇宙線
M–3	宇宙製造実用化試験	S–4	ガンマ線バースト
L–1	生物学	C–1	宇宙空間におけるRFI対策技術開発
L–2	宇宙医学	T–1	宇宙環境性能試験
L–3	生態系生命維持システム	T–2	大型アンテナシステム技術

Code	Mission Name	Code	Mission Name
M–1	Material Science Experiment	L–4	Biotechnology
M–2	Space Processing for Advanced Material	S–3	High Energy Cosmic Ray Experiment
M–3	Commercial Space Processing Test	S–4	γ Ray Burst Observation
L–1	Biology	C–1	RFI Technology Development
L–2	Space Medicine	T–1	Space Environment Test
L–3	CELS System Experiment	T–2	Large Antenna System Technology

FIGURE 11.—JEM schematic.

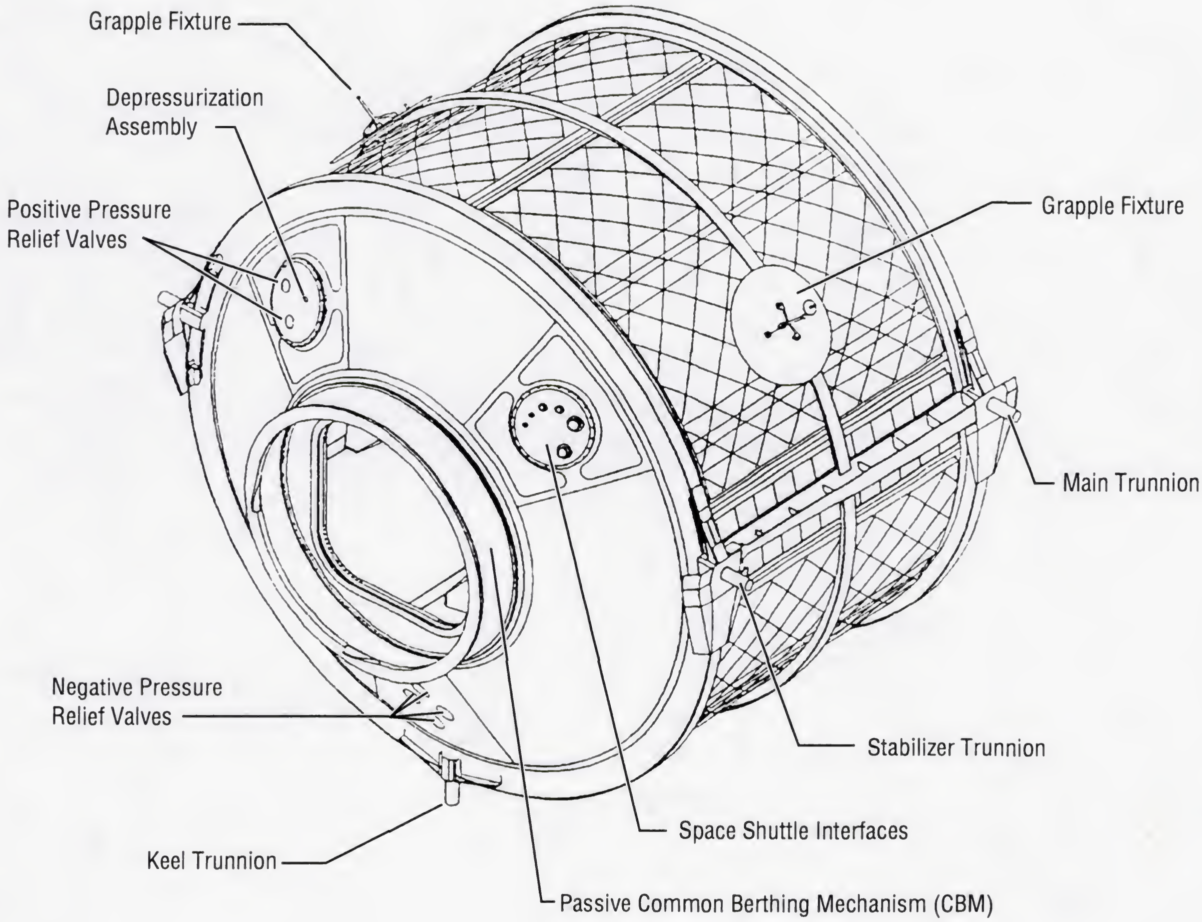


FIGURE 12.—MPLM schematic.

2.4 Construction of the *ISS* and the ECLSS Capabilities During Station Assembly

The assembly of the modules on orbit occurs over a period of $4^1/_2$ yr during Phase 2 (Flights 1A through 6A) and Phase 3 (Flights UF–1 through 19A) of the *ISS* assembly. The ECLSS capabilities present during construction are identified in table 1.

Table 1.—*ECLSS capability buildup by flight (as of April 1997).*

Flight Number	Module	Launch Date (23)	THC	FDS	ACS	AR	WRM	WM
1 A/R	FGB	June 1998	(1)	(2)	(3)	(22)		
2A	Node 1, PMA–1, PMA–2	July 1998	(4)	(2)				
1R	Service Module	December 1998	(6)	(2)	(7)	(8)	(9)	(16)
2R	Soyuz	January 1999	Self-contained, limited ECLSS					
5A	U.S. Lab	May 1999	(10)	(2)	(11)	(12)	(13)	
6A	U.S. Lab outfitted	June 1999	(10)	(2)	(11)	(14)	(13)	(16)
7A	Airlock	August 1999	(10)	(5)	(19)	(20)		
3R	UDM	December 2000	(1)		P_{tot}	CRF		
10A	Node 2	April 2000	(10)	(2)				
1J	JEM PM, etc.	August 2000	(10)	(2)				
16A	U.S. Hab	October 2002	(10)	(2)	(11)	(14)	(21)	(17)
17A	Hab racks	November 2002						
11R	Life Support Module 1	December 2002	(1)	(2)		(18)	(15)	(16)
12R	Life Support Module 2	January 2003	Information Not Available					
19A	Hab racks	April 2003						
UF7	Centrifuge	October 2003	TBD					
1E	ESA APM	December 2003	(10)	(2)				

Notes:

(1) No humidity control is provided, only sensible cooling (no latent cooling) (3 HX's in FGB, 2HX's in UDM and LSM), temperature sensor.

(2) Smoke detectors, PFE, and breathing masks.

(3) Basic atmospheric monitoring (O_2, CO_2, and H_2O (deactivated after Flight 1R), total and partial pressure) and pressure equalization.

(4) Atmospheric circulation fan available.

(5) Smoke detectors and PFE.

(6) Temperature and humidity control, equipment cooling, and CHX's.

(7) Addition of rate-of-pressure-change sensor (and tanks of resupply air on Progress vehicles).

(8) CO_2 removal (with LiOH backup), O_2 generator (with perchlorate candles as backup), TCCS, CO monitor.

(9) Processing of humidity condensate and storage of water.

(10) THC using internal thermal control system (ITCS) low-temperature coolant loop, IMV.

(11) Total pressure monitoring, vent and relief, O_2/N_2 distribution, pressure control assemblies (PCA's).

(12) High-efficiency particulate air (HEPA) filters for particulate and microorganism control.

(13) Condensate storage and distribution.

(14) Addition of AR rack (CDRA, TCCS, and Major Constituent Analyzer (MCA)).

(15) Addition of waste hygiene water processor and urine processor.

(16) Waste management provided by Russian SM or space shuttle (when present).

(17) Waste management in the U.S. Hab and Russian Service Module.

(18) CO_2 removal, O_2 generation, TCCS, CO monitor, and Sabatier.

(19) Addition of O_2/N_2 tanks.

(20) HEPA filters plus LiOH for CO_2 removal during campout.

(21) Addition of USOS potable water processor and urine processor.

(22) Filters for removal of gaseous and particulate contaminants and airborne microorganisms.

(23) All dates are approximate.

2.4.1 Phase 2—Flights 1A Through 6A

Flight 1A/R

The FGB is the first module launched. Although the United States provided funds for this module, it is Russian designed and manufactured and is included in the description of the Russian ECLSS in Volume II of this report. Onboard atmospheric monitoring is performed via cabin sensors for monitoring total and partial pressure (via a gas analyzer for monitoring O_2, CO_2, and H_2O). Three sensible heat exchangers maintain proper atmospheric temperatures. No latent cooling (humidity removal) is possible at this stage. Particulate and gaseous atmospheric contaminants are removed by Contaminant Removal Filters (CRF) and a Hazardous Contaminants Filter (HCF). FDS equipment includes smoke detectors, PFE, and PBA masks. No water recovery or waste management capability is present at this stage.

Flight 2A

Node 1, PMA–1, and PMA–2 are added with Flight 2A. The ECLSS functions on these components are limited to fire detection (smoke sensors) and atmospheric circulation (when power is available) with HEPA filters for particulate removal. There is no active cooling capability, however, so these functions are considered secondary in order to maintain the Remote Power Control Modules (RPCM) in operation, which are passively cooled by radiating heat to the structure. Node 1 is passively cooled from the Lab. The PMA's include ventilation ducting for exchanging atmosphere with the RS or the space shuttle to mix atmosphere for maintaining appropriate O_2 and CO_2 levels. In addition, PMA–2 includes plumbing for transferring high-pressure O_2/N_2 gases and fuel-cell water from the space shuttle.

Flight 1R

The Russian SM is installed with Flight 1R, which adds the capabilities of O_2 generation, CO_2 removal, trace contaminant removal, THC, and water processing. The SM ECLS equipment includes a total pressure sensor for cabin pressure monitoring; a gas analyzer to detect O_2, CO_2, and H_2O; and an analog pressure gauge, a pressure alarm sensor, and a rate-of-pressure-change (dP/dt) sensor to detect loss of atmospheric pressure.

AR hardware includes a Vozdukh CDRA that collects CO_2 and vents it overboard, an Elektron Oxygen Generation Assembly (OGA) (sized for three people) to provide metabolic O_2 needs, and a low-temperature catalytic oxidizer and regenerable absorber for trace contaminant removal. Backup capabilities are provided by LiOH canisters for CO_2 removal, a Solid-Fuel Oxygen Generator (SFOG) with oxygen perchlorate candles for O_2 supply, and CRF's for trace contaminant control.

FDS in the SM is similar to the FDS in the FGB, with the addition of a master fire indicator panel.

THC maintains appropriate temperature and humidity levels in the cabin and equipment locations and collects humidity condensate with CHX's. The condensate is delivered to the WRM subsystem.

WRM includes a Condensate Water Recovery Subsystem (CWRS) to produce potable water and two 210 L (7.42 ft^3) Service Water Tanks (SWT) for potable water storage in the assembly compartment of the SM. Ten portable 22 L (0.78 ft^3) едв "bucket" tanks are used for transporting water and urine within the RS. Unprocessed wastewater is stored in portable tanks for disposal in the Progress or transferred to the SWT on the Progress, after it is emptied of potable water.

WM includes a commode and urinal that collects urine in a tank for disposal in the Progress. Other solid wastes are bagged and disposed of in the Progress.

Flight 2R

The Soyuz brings the first crew to *ISS* during Flight 2R. There is no significant change in ECLSS capability with this flight, but the flight does initiate permanent habitation with a three-person crew. The Soyuz ECLSS consists of atmospheric cabin pressure monitoring and ventilation exchange with the SM.

Flight 3R

The UDM is added with Flight 3R. There is no significant change in ECLSS capability with this flight.

Flights 5A and 6A

The U.S. Lab module is installed with Flight 5A and is outfitted with additional equipment during Flight 6A, adding considerable ECLSS capability to the USOS. During Flight 5A the crew enters Node 1 for the first time, and the Lab and Node 1 are occupied after the space shuttle departs.

The Lab ECLS functions include total pressure monitoring, vent and relief capability, and O_2/N_2 supply and distribution. The PCA's, to maintain total atmospheric and oxygen partial pressures, and MPEV's, for module-to-module pressure equalization, are located in the Lab endcones. (Cabin pressure maintenance and control is not possible until Flight 7A when the AL is delivered and high-pressure O_2/N_2 gas supply is available.)

At Flight 5A, AR consists of HEPA filters to remove microorganisms and particulates from the atmosphere. At Flight 6A, the MPLM delivers the Four-Bed Molecular Sieve CDRA, the TCCS, and the Major Constituent Analyzer (MCA). Plumbing for collecting atmosphere samples for the MCA is pre-integrated into the Lab. Interface connections are provided to allow installation of an OGA at a later time.

The FDS capability is similar to that in Node 1, consisting of two module smoke detectors and two PFE's. There is one smoke detector in the AR rack, and smoke detectors can be supported in all 13 payload racks. Each powered rack has ports for attaching a PFE. An indicator panel identifies the location of a fire.

The Lab THC is provided with the activation of the ITCS low-temperature coolant loop. IMV supply and return ensures atmospheric composition and temperature control in Node 1 also. IMV can operate when the hatches are open or closed.

A VS consisting of a Vacuum Exhaust Subsystem (VES) and a Vacuum Resources Subsystem (VRS) is incorporated in the Lab, for use when payloads require a vacuum source.

The WRM function consists of condensate water storage and distribution, and fuel cell water distribution. (The transfer of fuel-cell water from the space shuttle is performed after the Hab is activated.) Two vents in the forward endcone are available for expelling excess wastewater.

No capability for WM is provided at this time in the USOS. WM capability and potable water are provided from the Russian SM. Interface connections are provided in the Lab to add WRM and WM at a later time, if desired.

2.4.2 Phase 3—Flights 6R Through 18A

Flight 7A

Support for EVA tasks is provided by the space shuttle through Flight 7A (except for one EVA at the end of Flight 7A from the joint AL) and afterwards from the joint AL that is added during Flight 7A. The AL ECLS capability supports crew campout in the AL for denitrogenation (8 to 12 hr preceding an EVA) at 70.3 kPa (10.2 psia) and incorporates the distribution plumbing to service and recharge the EMU's. High-pressure tanks of O_2 and N_2 are mounted externally and are connected to the O_2/N_2 distribution plumbing for maintaining atmospheric pressure and supporting payload requirements. The AL includes FDS capability and a dedicated CHX/fan package for THC of the AL atmosphere.

Flight 10A

Node 2 is added during Flight 10A. Node 2 ECLS capabilities include THC (a cabin air assembly, including a fan and CHX) and FDS (smoke sensors and PFE's). The condensate from the CHX is plumbed to the water processor in the Lab.

Flight 1J

The JEM is installed during Flight 1J. To a large extent, the JEM relies on the USOS for ECLS functions. The ECLS functions that are performed in the JEM are listed in section 2.3. Limited information is presently available on the methods that are used to provide the required capabilities.

Flight 11R

The LSM is installed during Flight 11R. The LSM provides atmospheric monitoring and FDS. In addition, the LSM provides CO_2 collection and removal for conversion of CO_2 to water in a Sabatier reactor, integrating CO_2 removal and O_2 generation into one unit. The gaseous byproducts (methane (CH_4) and CO_2) are vented to space. The LSM includes a processor to reclaim water from urine.

Flight 1E

The ESA APM is installed during Flight 1E. To a large extent, the APM relies on the USOS for ECLS functions. The ECLS functions that are performed in the APM are listed in section 2.3. Limited information is presently available on the methods that are used to provide the required capabilities.

Flight UF7

The centrifuge is added with Flight UF7. The ECLSS capabilities in the centrifuge include total atmospheric pressure sensor, THC, IMV, atmosphere composition monitoring (sample port), FDS (TBD), and a wastewater return line. No detailed information is available on the centrifuge ECLSS.

Flights 16A, 17A, and 19A

The U.S. Hab is installed and outfitted during Flights 16A, 17A, and 19A. Flight 19A is the final assembly flight of the USOS. The Hab includes sleeping accommodations, a galley, a shower, and a commode. ECLS capabilities are AR (CO_2 removal, O_2 generation, major constituent analysis, and TCCS; the necessary plumbing and electrical interface connections may also be available to add CO_2 reduction later), ACS, THC, FDS, WRM (condensate and hygiene waste water and urine processing), and WM (commode and urinal). The Hab provides redundancy for those ECLS functions which are also performed in the Lab. MCA capabilities are the same as in the Lab, with additional trace contaminant monitoring capability provided by the CHeCS VOA. Trace contaminants are removed by a TCCS in the Hab or Lab. THC capability is provided by one common cabin air assembly (CCAA) in the Hab and two CCAA's in the Lab. IMV supply and return is provided via a fan and ducts in each endcone configured so that IMV can occur when the hatches are open or closed.

The ECLSS equipment installed in the Hab allows the USOS to be "self-sufficient" with regard to providing the ECLSS services. There is still some atmosphere exchange with the RS through the FGB, and so water transfer may be necessary to maintain mass balances.

3.0 *ISS* Segment ECLSS Specifications

For each *ISS* segment, the capabilities that are provided are documented in segment specification documents and in Capability Description Documents (CDD). The specifications establish the performance, design, development, and verification requirements for each segment. The performance requirements of each segment as a whole are defined, as well as the performance requirements of the major components which comprise each segment. Requirements are based on the functions to be performed or on constraints with which the design must comply. The ECLS systems specifications for each segment are described below.

3.1 ECLSS Performance Requirements

Basic *ISS* requirements, as well as the specific ECLS requirements, affect the ECLSS design. General requirements include limiting atmospheric leakage for each module to a maximum of 0.23 kg/day at 101.3 kPa (0.5 lb/day at 14.7 psia) with a goal of considerably less leakage (an overall rate of no more than 0.68 kg/day (1.5 lb/day)). The ECLS requirements are listed in table 2. The USOS requirements also apply to the JEM, APM, and MPLM, except where noted otherwise. The metabolic loads that must be accommodated are listed in table 3. There are some differences between the U.S. and Russian requirements and specifications. These are discussed in the following section.

3.2 Design Philosophies

The basic philosophies of design that are used by the United States and Russia have some significant differences that must be understood to ensure that the different ECLS systems are compatible. In addition, differences in terminology can lead to confusion. For example, the word "monitor" may be translated into Russian as "control" when the intended meaning is "measure."

For example, the U.S. approach to ensuring that a capability is provided tends toward using redundant equipment, i.e., having two identical units with one used only in an emergency or operating both at less than their full capability. This leads to having two CO_2 removal units, for example, with one in the Hab and one in the Lab, each of which can accommodate the entire normal load. There are exceptions to this approach, e.g., there is only one water processor and one commode. In comparison, the Russian approach is to have an alternative backup rather than a redundant unit, e.g., for oxygen supply if the Elektron O_2 generator fails, the backup is the SFOG and stored O_2 (gas, liquid, or solid form) for use until a replacement unit is delivered. This method works because of the regular resupply missions. Again, there are exceptions, e.g., there are two fans in the FGB, one of which is for redundancy.

The basic design philosophy used for designing the U.S. ECLS system includes:

- Minimize the use of expendable materials by using regenerable methods where feasible, e.g., for CO_2 removal, urine processing, etc.

- Recover as much mass as possible (i.e., close the mass loops) when cost effective, e.g., recovery of the atmospheric moisture during CO_2 removal.

- Minimize the amount of redundancy required (i.e., during assembly by adjusting the installation sequence, by appropriate planning of operations, or by relying on the RS to provide redundancy).

- Design for minimum risk of failure of mechanisms, structures, pressure vessels, materials, etc.

The failure tolerance for many of the ECLSS functions is zero (i.e., the function is lost when the equipment fails) at the module level. Exceptions to this are intermodule ventilation and intramodule ventilation, heat collection and distribution, and response to hazardous atmosphere, which must be single-failure tolerant. However, for the complete *ISS*, there is redundancy for critical functions.

Another example of the effect of different philosophies is the design of the OGA. The United States and Russia both use electrolysis of water as the basic technique, but there are significant design differences. The U.S. approach is to design hardware to be serviceable, so components are designed as orbital replaceable units (ORU) and are accessible for replacement. Safety concerns due to the presence of hydrogen (H_2) as an electrolysis byproduct were dealt with by ensuring that the quantities of combustible gases present are negligible. The Russian approach does not require that components be individually replaceable. They also use a different approach to ensuring safety. As a result, for their OGA the electrolyzer was placed inside a pressurized N_2 jacket so that any leakage is into the electrolyzer. Also, when the OGA is turned off, the N_2 flushes O_2 and H_2 from the lines. This design precludes the possibility of any leakage of hazardous gases to the atmosphere, but individual components are not accessible for replacement.

As a result of the differences in design philosophy, integrating the Russian and U.S. ECLS systems must be done carefully. The equipment developed by the different approaches may not be compatible without some modification. Table 4 lists differences and similarities in the design philosophies of the U.S. and Russian ECLS designers.

TABLE 2.—*General ECLSS design requirements.*

Parameter	U.S. ECLS Requirements		Russian ECLS Requirements	
	Range (Metric Units)	Range (U.S. Units)	Range (Metric Units)	Range (U.S. Units)
Total Pressure	97.9 to 102.7 kPa (95.8 min)	14.2 to 14.9 psia (13.9 min)	79.9 to 114.4 kPa (93.0 normal min)	11.6 to 16.6 psia (4) (13.5 normal min)
Total Pressure Monitoring	0 to 110.6 kPa	0 to 16.0 psia	1 to 1,000 mmHg	0.02 to 19.4 psia
$ppCO_2$ (1)	0.705 to 1.011 kPa (5.3 to 7.6 mmHg) (0.705 kPa normal 24 hr average)	0.102 to 0.147 psia (0.102 psia average)	5.3 mmHg up to 3 people 7.6 mmHg up to 5 people 4.5 mmHg avg.	0.102 psia 0.147 psia 0.08 psia avg.
$ppCO_2$ Monitoring	0 to 2.0 kPa (15.0 mmHg)	0 to 0.29 psia ±1% FS	0 to 25 mmHg	0 to 0.48 psia
ppO_2	19.5 to 23.1 kPa (146 to 173 mmHg)	2.83 to 3.35 psia	19.5 to 23.1 kPa (146 to 173 mmHg)	2.83 to 3.35 psia
ppO_2 Monitoring	0 to 40 kPa	0 to 5.8 psia		
ppN_2	< 80 kPa	< 11.6 psia	< 80 kPa (< 600 mmHg)	< 11.6 psia
Relative Humidity	25 to 70%	25 to 70%	30 to 70%	30 to 70%
Relative Humidity Monitoring	Not monitored	Not monitored	1 to 35 mmHg (±1.5 mmHg accuracy)	1 to 35 mmHg (±1.5 mmHg accuracy)
Atmospheric Temperature (3)	17.8 to 26.7 °C	65 to 80 °F	18 to 28 °C	64.4 to 82 °F
Atmospheric Temperature Monitoring	15.6 to 32.2 °C ± 1.8 °C	60 to 90 °F ±1 °F		
Dewpoint	4.4 to 15.6 °C	40 to 60 °F	4.4 to 15.6 °C	40 to 60 °F
Intramodule Circulation	0.051 to 0.20 m/sec (0.036 to 1.02 m/sec, lower and upper limits)	10 to 40 fpm (7 and 200 fpm, lower and upper limits)	0.05 to 0.20 m/sec	9.8 to 39.4 fpm
Intermodule Ventilation	66 ± 2.4 L/sec	140 ± 5 cfm	60 to 70 L/sec	127 to 148 cfm
Fire Suppression ppO_2 Level	10.5%	10.5%		
Particulate Concentration (0.5 to 100 mm diameter)	Average < 0.05 mg/m^3 Peak < 1.0 mg/m^3	<100,000 particles/ft^3 <2,000,000 particles/ft^3	< 0.15 mg/m^3	< 0.15 mg/m^3
Temperature of Surfaces	4 °C < touch temperature < 45 °C 46 to 49 °C is acceptable for momentary contact	39 °F < touch temperature < 113 °F 114 to 120 °F is acceptable for momentary contact	> Dewpoint	> Dewpoint
Atmospheric Leakage (2) per Module	Max. of 0.23 kg/day at 101.3 kPa	0.5 lb/day at 14.7 psia	< 0.02 kg/day (Pressure not specified; assume 101.3 kPa)	< 0.009 lb/day

Notes:

(1) During crew exchanges the maximum daily average $ppCO_2$ is 1.01 kPa (7.6 mmHg), with a peak of up to 1.33 kPa (10 mmHg).

(2) Total atmospheric leakage is to be less than 0.68 kg/day (1.5 lb/day), although the ability to accommodate 2.04 kg/day (4.5 lb/day) leakage is to be present.

(3) For Node 1, the cupola, and the MPLM, the requirement is 17.8 to 29.4 °C (65 to 85 °F) since these modules do not have a CCAA.

(4) The RS total pressure requirement encompasses the USOS requirement. Since the USOS controls the total atmospheric pressure, the total pressure will meet the USOS requirement.

Table 3.—*Metabolic design loads.*

Parameter	U.S. ECLS Loads Standard Value	U.S. ECLS Loads Range	Russian ECLS Loads Standard Value	Russian ECLS Loads Range
Crew O_2 Consumption	0.84 kg/person/day 1.84 lb/person/day	0.49 to 1.25 1.08 to 2.76	0.86 kg/day/person 1.89 lb/day/person	
Experiment O_2 Consumption	120 g/day 0.26 lb/day	TBD TBD		
Animal O_2 Consumption	1.08 kg/day 2.38 lb/day			
Crew Heat Loads	137 W/person	TBD		
Experimental Animals Heat Loads (1)	6 W	TBD		
Crew-Generated Moisture	1.82 kg/day/person 4.01 lb/day/person	0.87 to 4.30 1.92 to 9.48		
Animal-Generated Moisture (1)	136 g 0.30 lb	TBD TBD		
Crew Water Consumption	2.8 kg/day/person 6.2 lb/day/person	Up to 5.15 Up to 11.35	2.5 L/day/person 5.5 lb/day/person	
Crew Hygiene Water Usage	6.8 kg/day/person 15.0 lb/day/person	Up to 7.3 Up to 16.0	1.1 kg/day/person (SM only) 2.42 lb/day/person (SM only) 4.53 kg/day/person (SM and LSM) 9.96 lb/day/person (SM and LSM)	
Crew Urine Production	1.56 kg/day/person 3.43 lb/day/person	Up to 2.0 Up to 4.4	1.2 kg/day/person 2.64 lb/day/person	
Microbial Generation Rate	3,000 CFU/person/min	N/A		
Particulate Generation Rate	1×10^9 pcs/person/day	N/A		
Crew CO_2 Generation Rate	1.00 kg/person/day 2.20 lb/person/day	0.52 to 1.50 1.14 to 3.30	1.00 kg/day/person (2) 2.20 lb/day/person	
Animal CO_2 Generation Rate (1)	136 g/day 0.30 lb/day	TBD TBD		

Notes:

(1) These values are for 72 rodents. Up to 72 rodents (or an equivalent metabolic load) may be accommodated.

(2) The CO_2 generation rate is based on CO_2 releases of 13.5 L/hr during sleep, 18.7 L/hr during light work, and 72 L/hr during exercise (0006A4a, p. 26).

TABLE 4.—*ECLS philosophy differences and similarities.*

	Russian	U.S.
Trace Contaminant Detection/Control Before Entry	No capability to verify clean air prior to entering a module. For the FGB and SM, a special filter is activated 2 days prior to first entry. Other modules are purged prior to launch and attached before offgassing contaminates the atmosphere.	Samples may be collected through the MPEV and analyzed before opening the hatch by CHeCS instrumentation. Node 1 has filters to remove contaminants prior to ingress.
Trace Contaminant Removal	Trace contaminant removal equipment sizing considers that atmospheric contaminants are removed by the humidity control assembly and due to atmospheric leakage to space.	Trace contaminant removal equipment sizing does not consider other ways in which atmospheric contaminants are removed. Therefore the design is conservative.
Trace Contaminant Generation	Generation rate prediction is based on the surface area of materials.	Generation rate prediction is based on the mass of nonmetallic materials.
SMAC Level Selection	SMAC levels are based on the capabilities of the available TCCS technologies, as well as health reasons.	SMAC levels are based on the best information available concerning possible health impacts of contaminants.
(Note: A result of this different approach is that Russian SMAC values tend to be smaller than U.S. SMAC values. The U.S. TCCS equipment is capable, however, of maintaining concentrations well below the SMAC values for most compounds.)		
Failure Tolerance	For repairable systems there could be many failures with *no long-term loss of function.* Loss of one leg of redundancy does not mean that a system has failed.	Specified for each function and system. ECLS *functions are zero- or one-failure* tolerant. One-failure-tolerant hardware requires a redundant functional path.
Response to Rapid Decompression	Protect from rapid depressurization rather than design for depressurization.	Design for depressurization, as well as protect from depressurization.
Internal Hatches	Operable from the inside only (EVA hatch and Progress cargo hatch).	All hatches operable from both sides (except for the AL hatch).
Intermodule Ventilation	Drag-through ducts that must be disconnected before the hatches can be closed.	Hard ducts that allow IMV with the hatches closed.
Fire Protection	Nonflammable or slow-burning materials are used where possible. Smoke detectors and PFE's are provided.	Nonflammable or slow-burning materials are used where possible. Smoke detectors and PFE's are provided.
Emergency Equipment —Breathing Masks	Emergency mask generates O_2 by chemical reaction of CO_2 and water vapor with the material in the mask.	Emergency mask has a supply of gaseous O_2.
Overall Water Recovery Architecture	Separate recovery of condensate, waste hygiene, and urine water; recovered condensate reserved for potable use; recovered urine reserved for electrolysis.	Recovered urine water is combined with all other waste waters and processed to potable specification for reuse in all applications.
Water Quality Measurement	On-line measurement of conductivity only. Off-line measurement of samples returned to Earth.	On-line measurement of conductivity, pH, iodine, and TOC. Off-line measurement of microorganisms, TOC, and specific ions.
Biocide in Water	Ag	I_2
(Note: There is an integration concern that if the waters are mixed, AgI_2 would precipitate out, removing biocide activity and potentially clogging lines.)		

TABLE 4.—*ECLS philosophy differences and similarities (continued).*

	Russian	U.S.
Metabolic Design Requirements	**O_2 Consumption:** 0.86 kg/day/person (1.89 lb/day/person) **CO_2 Production:** 1.00 kg/day/person (2.20 lb/day/person)	**O_2 Consumption:** 0.84 kg/day/person (1.84 lb/day/person) **CO_2 Production:** 1.00 kg/day/person (2.20 lb/day/person)
Oxygen Concentration	Materials must be compatible with 40% ppO_2.	Materials must be compatible with 24.1% ppO_2 (except for the AL, where the maximum is 30% ppO_2).
Oxygen Supply	**During Normal Operation:** 100% generated by electrolysis **During Crew Exchange or Other Off-Nominal Condition:** 75% generated by electrolysis and 25% from perchlorate or other source.	**Initial Operation:** Supplied by RS or shuttle **After the Hab OGA is Operating:** 100% is generated by electrolysis. (O_2 for EVA's is resupplied from the space shuttle in tanks.)
CO_2 Partial Pressure	5.3 mmHg (0.10 psia) with a maximum 7.6 mmHg (0.147 psia).	See figure 93.
(Note: During crew exchange, the specifications allow 7.6 mmHg with peaks to 9.9 mmHg.)		
Humidity Removal	Moisture is removed from the atmosphere as necessary. Temperature control and humidity removal are separate functions.	Moisture is removed from the atmosphere continuously. Temperature control and humidity removal are performed by the same device.
Operating Pressure	79.9 to 114.4 kPa (11.6 to 16.6 psia) 93.0 kPa (13.5 psia) normal minimum. (In operation, the RS total pressure matches the USOS.)	97.9 to 102.7 kPa (14.2 to 14.9 psia) 95.8 kPa (13.9 psia) normal minimum.
Crew Accommodation	With the SM, three people normally with up to five during crew exchange. After activation of the LSM, six people normally with TBD during crew exchange.	After the Hab is activated, six people normally, and TBD during crew exchange (includes space shuttle and JEM/APM).
EVA Atmosphere	Prior to activation of the DM, venting of atmosphere in the AL for EVA. After activation of the DM, recovery of atmosphere in the AL prior to EVA.	Recovery of atmosphere in the AL prior to EVA.
EVA Suits	36.5 kPa (5.3 psia).	29.66 kPa (4.3 psia).
Shower Water Usage	One 10 L (0.35 ft^3, 22 lb) shower per person each week.	5.5 L (0.19 ft^3, 12 lb) shower every 2 days per person.
Food Supply	Almost all food is dehydrated and requires potable water to rehydrate.	Diet includes moist food, which provides a source of water to the system.
Potable Water	Minerals are added to the processed condensate water, which add flavor and provide a pH-balanced water.	No additives to the potable water.
Hardware Location	When possible, hardware items performing related or connected functions are located in the same module to avoid the need to plumb fluids between modules.	When possible, hardware items performing related or connected functions are located in the same module, however, fluids are plumbed between modules.
Hardware Maintenance	Components are replaced after failure or based on statistical expectation of failure.	Components are replaced after failure or, for limited life items, on a scheduled basis.

Another difference relates to identifying and correcting problems. During normal station operations, the Russians maintain an identical system on the ground operating concurrently with the flight unit. This approach allows for hardware problems to be anticipated and corrective actions to be implemented before a problem develops on orbit, since the ground unit begins operation before the flight unit. An additional new unit is kept on the ground, and it is assumed that it would replace the flight unit if that unit failed and was not repairable on orbit. The United States does not have such a duplicate of the USOS.

3.3 *ISS* ECLS Capabilities

The ECLS capabilities are described in this report as shown in table 5. This lists the capabilities as they are described in the segment specifications. There is some variation between the segment specifications, but table 5 is comprehensive. More detail is provided in chapters 2 and 3, and in Volume II (distribution restricted to Governmental agencies) of this report.

TABLE 5.—ISS *ECLS capabilities.*

	RS	USOS	JEM	APM	MPLM
ACS					
• Control Total Atmospheric Pressure					
– Monitor Total Atmospheric Pressure	√	√	√	√	√
– Introduce Nitrogen	√	√	N/A (1)	N/A (1)	N/A (1)
• Control Oxygen Partial Pressure					
– Monitor Oxygen Partial Pressure	√	√	√	√	N/A (1)
– Introduce Oxygen	√	√	N/A (1)	N/A (1)	N/A (1)
• Relieve Overpressure	√	√	√	√	√ (3)
• Equalize Pressure	√	√	√	√	√
• Respond to Rapid Decompression					
– Detect Rapid Decompression	√	√	N/A (1)	N/A (1)	N/A (1)
– Recover From Rapid Decompression	X	√	√ (6)	√ (6)	√ (6)
• Respond to Hazardous Atmosphere					
– Detect Hazardous Atmosphere	X	√	√	√	√
– Remove Hazardous Atmosphere	X	√	√	√	√
– Recover From Hazardous Atmosphere	√	√	√	√	√
THC					
• Control Atmospheric Temperature					
– Monitor Atmospheric Temperature	√	√	√	√	N/A (1)
– Remove Atmospheric Heat	√	√	√	√	N/A (1)
• Control Atmospheric Moisture					
– Monitor Humidity	√	X	N/A	N/A	N/A
– Remove Atmospheric Moisture	√	√	√	√	N/A (1)
– Dispose of Removed Moisture	√	√	√ (7)	√ (7)	N/A (1)
• Circulate Atmosphere: Intramodule	√	√	√ (2)	√ (2)	√ (2)
• Circulate Atmosphere: Intermodule	√	√	√ (2)	√ (2)	√ (2)
AR					
• Control CO_2					
– Monitor CO_2	√	√	√	√	N/A (1)
– Remove CO_2	√	√	√ (5)	√ (5)	√ (5)
– Dispose of CO_2	√	√	N/A (1)	N/A (1)	N/A (1)
• Control Gaseous Contaminants					
– Monitor Gaseous Contaminants	√	√	√ (4)	√ (4)	√ (4)
– Remove Gaseous Contaminants	√	√	√ (5)	√ (5)	√ (5)
– Dispose of Gaseous Contaminants	√	√	N/A (1)	N/A (1)	N/A (1)
• Control Airborne Particulate Contaminants					
– Remove Airborne Particulate Contaminants	√	√	√	√	N/A
– Dispose of Airborne Particulate Contaminants	√	√	√	√	N/A
• Control Airborne Microbial Growth					
– Remove Airborne Microorganisms	√	√	√	√	N/A
– Dispose of Airborne Microorganisms	√	√	√	√	N/A

TABLE 5.—ISS *ECLS capabilities (continued).*

	RS	USOS	JEM	APM	MPLM
FDS					
• Respond to Fire					
– Detect a Fire Event	√	√	√	√	√
– Isolate Fire Control Zone	√	√	√	√	√
– Extinguish Fire	√	√	√	√	√
– Recover From a Fire	X	√	√	√	N/A
WM					
• Accommodate Crew Hygiene and Wastes	√	√	N/A	N/A	√ (8)
WRM					
• Provide Water for Crew Use					
– Monitor Water Quality	√	√	N/A	N/A	N/A
– Supply Potable Water	√	√	N/A	N/A	N/A
– Supply Hygiene Water	√	√	N/A	N/A	N/A
– Process Wastewater	√	√	N/A	N/A	N/A
• Supply Water for Payloads	√	√	√	√	N/A
VS					
• Supply Vacuum Services to User Payloads					
– Provide Vacuum Exhaust	N/A	√	√	√	N/A
– Provide Vacuum Resource	N/A	√	√	√	N/A
EVA Support					
• Support Denitrogenation					
– Support In-Suit Prebreathe	√	√	N/A	N/A	N/A
– Support Campout Prebreathe	X	√	N/A	N/A	N/A
• Support Service And Checkout					
– Provide Water	√	√	N/A	N/A	N/A
– Provide Oxygen	√	√	N/A	N/A	N/A
– Provide In-Suit Purge	X	√	N/A	N/A	N/A
• Support Station Egress					
– Evacuate Airlock	√	√	N/A	N/A	N/A
• Support Station Ingress					
– Accept Wastewater	√	√	N/A	N/A	N/A
Other					
• Distribute gases to user payloads	N/A	√	√	√	N/A

Notes:
√ indicates that a capability is provided.
X indicates that a capability is not provided.
N/A indicates that a capability requirement does not apply to this segment
(1) This capability is provided by the USOS.
(2) This capability is performed using the same method as that of the USOS.
(3) The MPLM capability to relieve overpressure is disabled when the MPLM is attached to the USOS.
(4) Gaseous contaminants (including H_2 and CH_4) are monitored in the USOS with samples provided via the Sample Delivery System (SDS) from the APM, JEM, and MPLM.
(5) CO_2 and gaseous contaminants are removed by IMV with the USOS, where the CDRA and TCCS are located.
(6) Recovery from decompression is by pressure equalization with Node 2 (for the APM and MPLM), or by O_2 and N_2 supplied from the USOS (for the JEM).
(7) Moisture that is collected from the CHX is delivered, via tubing, to the USOS water processor (WP).
(8) Wastes are returned to Earth in the MPLM.

3.3.1 RS ECLS Capabilities

The specified RS ECLSS capabilities are listed below:

Control Total Atmospheric Pressure

The atmospheric total pressure is manually monitored over the range of 0 to 960 mmHg (0.0 to 18.5 psia) with an accuracy of ±2 mmHg (0.04 psia). The atmospheric total pressure is automatically monitored over the range of 1 to 1,000 mmHg (0.02 to 19.4 psia) with an accuracy of ±30 mmHg (0.58 psia). The total pressure is maintained between 734 and 770 mmHg (14.2 and 14.9 psia) with a minimum pressure of 700 mmHg (13.5 psia). N_2 is added to replenish losses, but the ppN_2 is maintained below 600 mmHg (11.6 psia). The cargo vehicle has the capability to introduce atmospheric gases (nitrogen, oxygen, or air) into the habitat to maintain the atmospheric pressure.

Control Oxygen Partial Pressure

The ppO_2 is monitored over a range of 0 to 300 mmHg (0 to 5.8 psia) with an accuracy of ±12 mmHg (0.23 psia). The ppO_2 is maintained between 146 an 173 mmHg (2.83 and 3.35 psia) with a maximum concentration of 24.8 percent by volume. Oxygen is added at a rate of 0.86 kg/person/day (1.89 lb/person/day) for three people during normal operations and six people during crew transfer operations.

Relieve Overpressure

The total pressure is maintained below the maximum allowable design pressure for the *ISS*, the maximum allowable design pressure is 104.7 kPa (15.2 psia, 786 mmHg). The RS modules are designed to accommodate pressures as high as 128.8 kPa (18.7 psia, 970 mmHg).

Equalize Pressure

The pressure differential between adjacent, isolated volumes at 775 mmHg (15.0 psia) and 740 mmHg (14.3 psia) can be equalized to less than 0.5 mmHg (0.01 psia) within 3 min.

Control Atmospheric Temperature

The atmospheric temperature is monitored over the range of 15.5 to 32.2 °C (60 to 90 °F) with an accuracy of ±1 °C (2 °F). The atmospheric temperature in the cabin aisleway is maintained within the range of 18 to 28 °C (64 to 82 °F) and within ±1.5 °C (3 °F) of the selected temperature.

Control Atmospheric Moisture

The atmospheric relative humidity in the cabin aisleway is maintained within the range of 30 to 70 percent, the dewpoint within the range of 4.4 to 15.6 °C (40 to 60 °F), and the water vapor pressure is monitored over a range of 1 to 35 mmHg (0.02 to 0.68 psia) with an accuracy of ±1.5 mmHg (0.029 psia). For the Soyuz, while attached to the *ISS*, the dewpoint is maintained in the range of 4.4 to 14.0 °C (40 to 57 °F).

Moisture removed as humidity condensate is delivered at an average rate of 1.5 kg/person/day (3.3 lb/person/day) to the SM water processor.

Circulate Atmosphere Intramodule

The effective atmospheric velocity in the FGB cabin aisleway is maintained within the range of 0.05 to 0.2 m/sec (10 to 40 fpm). The effective atmospheric velocity pertains to the time-averaged velocity in the cabin, using averages over time periods sufficient to achieve stability. Two-thirds of the local velocity measurements are within the design range, with a minimum velocity of 0.036 m/sec (7.1 fpm) and a maximum velocity of 1.02 m/sec (200 fpm). Atmospheric velocities within 15 cm (6 in) of the cabin interior surfaces are not considered.

Circulate Atmosphere Intermodule

The SM exchanges atmosphere with the USOS at a rate of 60 to 70 L/sec (127 to 148 cfm).

Respond to Fire

Fire safety criteria are shown in figure 13. Isolation of the fire (by removal of power and forced ventilation in the affected location) will occur within 30 sec of detection. Detection of a fire will initiate a Class I alarm and a visual indication of the fire event will be activated. Forced ventilation between modules will stop within 30 sec of annunciation of a Class I fire alarm. PBA's and PFE's are provided.

Fires will be suppressed using PFE's within 1 min of suppressant discharge. The capability to restore the habitable environment after a fire event is present.

Respond to Rapid Decompression

A decompression of more than 90 mmHg per hr (1.74 psi per hr) will be detected and a Class I alarm will be activated when such a decompression rate is detected.

Respond to Hazardous Atmosphere

PBA's (breathing masks) with a 15-min supply of O_2 (generated by chemical reaction from CO_2 and water vapor) are provided for each crew member. The FGB provides such capability for three people.

Accommodate Crew Hygiene and Wastes

Facilities are provided for personal hygiene and collection, processing, and disposal of crew metabolic waste. The wastes include menstrual discharge and associated absorbent material; emesis; fecal solids, liquids, gases, and particulates; urine and associated consumable material; soap, expectorants, hair, nail trimmings, and hygiene water; and crew wastes collected during EVA's. Facilities are provided for personal grooming, including skin care, shaving, hair grooming, and nail trimming. Simultaneous whole body skin and hair cleaning are accommodated.

Control CO_2

The atmospheric $ppCO_2$ is maintained at a maximum daily average of 4.50 mmHg (0.08 psia), with peak levels no greater than 7.60 mmHg (0.147 psia). CO_2 is removed and disposed of at an average rate of 0.96 kg/person/day (2.12 lb/person/ day) for three people during normal operations and six people during crew exchanges. The $ppCO_2$ level is monitored over a range of 0.00 to 25.00 mmHg (0.00 to 0.48 psia) with an accuracy of ±2.00 mmHg (0.038 psia).

Control Gaseous Contaminants

Atmospheric trace gas contaminants that are generated during normal operations are maintained at levels below the Maximum Allowable Concentration (MAC) levels. The removed gases are discarded. The MAC levels are listed in table 6. Provisions are made to accom-modate the U.S. air monitoring equipment according to SSP 50065, the CHeCS to RS ICD.

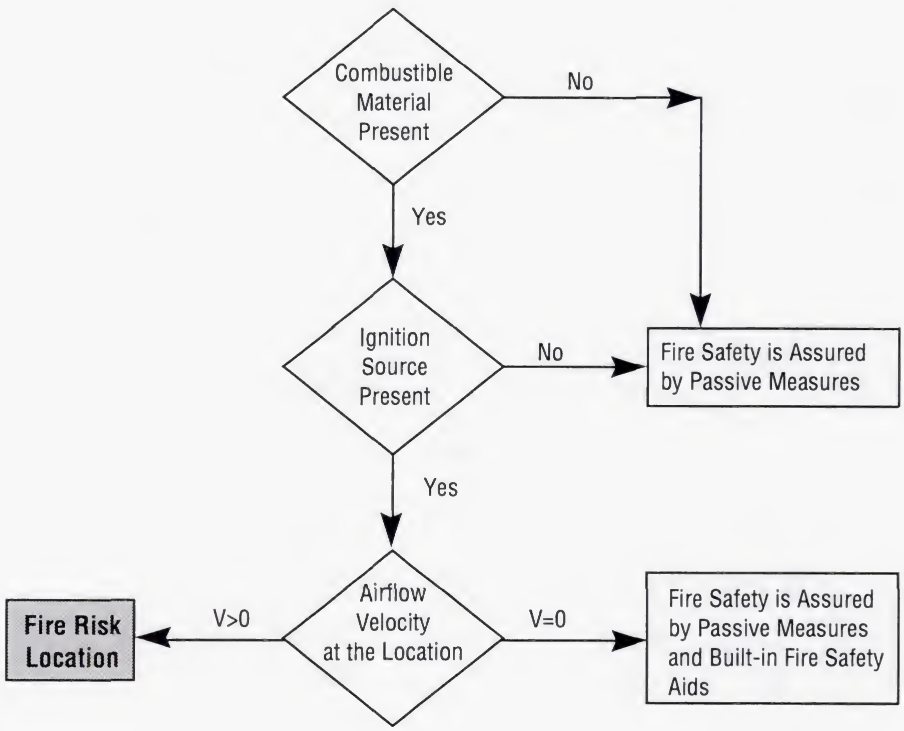


FIGURE 13.—RS fire safety criteria (0006A8a, p. 17).

TABLE 6.—*Russian allowable concentrations of gaseous contaminants.*

Chemical	Allowable Concentration (mg/m^3) for Potential Exposure Period					
	15 Days	30 Days	60 Days	90 Days	180 Days	360 Days
Acetaldehyde	–	–	–	–	–	1.0
Acetic Acid (Fatty Acid)	10.0	3.0	1.0	1.0	0.5	0.5
Acetone	5.0	3.0	1.0	1.0	1.0	1.0
Ammonia	5.0	2.0	2.0	1.0	1.0	1.0
Benzene	–	–	–	–	0.2	0.2
1-Butanol	–	–	–	–	–	0.8
N-Butyl Acetate	–	–	–	–	–	2.0
Carbon Monoxide	10.0	10.0	10.0	10.0	5.0	5.0
Cyclohexane	–	–	–	–	–	3.0
1,2-Dichloroethane	–	–	–	–	–	0.5
Ethanol	–	–	–	–	–	10.0
Ethylacetate	–	–	–	4.0	4.0	4.0
Ethyleneglycol	100.0	–	–	–	–	–
Formaldehyde	–	–	–	–	–	0.05
Heptane	–	–	–	–	–	10.0
Hydrocarbon (Total C)	100.0	50.0	50.0	50.0	20.0	20.0
Hydrogen (%/vol)	–	–	–	–	–	2.0
Hydrogen Fluoride	–	–	–	–	–	0.01
Hydrogen Sulfide	–	–	–	–	–	0.5
Isopropylbenzene	–	–	–	–	–	0.25
Methane (%/vol)	0.5	0.5	0.5	0.5	0.5	0.5
Methanol	–	–	–	–	–	0.2
Methyl Ethyl Ketone	–	–	–	–	–	0.25
Nitric Oxide	–	–	–	–	–	0.1
Octane	–	–	–	–	–	10.0
Phenol	–	–	–	–	–	0.1
Styrene	–	–	–	–	–	0.25
Toluene	–	–	–	–	–	8.0
Xylenes (m-, o-, or p-)	–	–	–	–	–	5.0

Control Airborne Particulate Contaminants

The daily average concentration of airborne particulates is limited to less than 0.15 mg/m^3 for particles from 0.5 to 300 microns in size.

Control Airborne Microbial Growth

The daily average concentration of airborne microorganisms is limited to less than 1,000 CFU/m^3. (Present Russian capabilities can limit airborne microbes to 500 CFU/m^3 for bacteria and to less than 100 CFU/m^3 for fungi.) Microbial monitoring is performed using U.S. and Russian equipment.

Provide Water for Crew Use

An average of 2.5 kg/person/day (5.5 lb/person/day) of potable water is provided for six people for food rehydration, consumption, and oral hygiene. The SM provides an average of 1.1 kg/person/day (2.42 lb/person/day) of hygiene water for three people. After activation of the LSM, the LSM and SM combined provide an average of 4.53 kg/person/day (9.96 lb/person/day) of hygiene water. The qualities of the waters meet the specifications defined in the "System Specification for the International Space Station," SSP41000E, 3 July 1996.

Humidity condensate is processed to potable water quality. Urine is collected and disposed of at an average rate of 1.2 kg/person/day (2.64 lb/person/day). This function is performed in the SM until the LSM is activated. After activation of the LSM, urine is processed and provided to the Elektron to produce breathing oxygen.

To monitor the water quality, the SM accommodates U.S. provided water monitoring equipment, according to

SSP 50065, the CHeCS to RS ICD. Sample ports for manual collection of water samples are provided to facilitate off-line monitoring and analysis of processed water, and for archiving of water samples.

Support Station Ingress

The DC supports the controlled, tethered entry into the RS by a person in a pressurized spacesuit. The DC supports repressurization from vacuum to the RS atmospheric pressure at a nominal repressurization rate of 5 mmHg per sec. The maximum emergency repressurization rate is 10 mmHg per sec. In the event of an emergency during an EVA, an unimpaired crew member can reenter the AL within 30 min.

Distribute Gases to User Payloads

This capability is not presently required on the RS.

3.3.2 USOS ECLS Capabilities

The USOS ECLSS maintains the required atmospheric composition for six crew members for CO_2 removal and trace contaminant removal, and TBD crew members for metabolic O_2.

The onboard equipment required for station survival is serviceable in the pressure range of 60 to 107 kPa (450 to 800 mmHg, 8.7 to 15.5 psia). All onboard equipment will also operate after being exposed to a minimum pressure of 60 kPa (450 mmHg, 8.7 psia) after the pressure has been restored to a minimum pressure of 93.3 kPa (700 mmHg, 13.5 psia).

The USOS ECLSS capabilities are described below:

Control Total Atmospheric Pressure

The atmospheric total pressure is monitored over the range of 0.0 to 110.6 kPa (0.0 to 827 mmHg, 0.0 to 16 psia) with an accuracy of ±0.07 kPa (0.5 mmHg, 0.01 psia). The total pressure is maintained nominally between 97.9 and 102.7 kPa (734 and 771 mmHg, 14.2 and 14.9 psia), with a minimum pressure of 95.8 kPa (719 mmHg, 13.9 psia). The ppN_2 is kept below 80 kPa (600 mmHg, 11.6 psia). N_2 is stored in high-pressure tanks (at least 850 L (30 ft^3)) at pressures up to 23.4 MPa (3400 psia). The tanks are recharged from the space shuttle.

Control Oxygen Partial Pressure

The atmospheric ppO_2 is monitored over a range of 0.0 to 40 kPa (0.0 to 300 mmHg, 0.0 to 5.8 psia) with an accuracy of ±2 percent of full scale. The ppO_2 is maintained between 19.5 and 23.1 kPa (146 and 173 mmHg, 2.83 and 3.35 psia) with a maximum concentration of 24.1 percent by volume. O_2 is added at a rate of 0.83 kg/person/day (1.84 lb/person/day) for four people and 1.08 kg/day (2.38 lb/day) for animal metabolic needs. O_2 is stored in high-pressure tanks (at least 850 L (30 ft^3)) at pressures up to 23.4 MPa (3,400 psia). The tanks are recharged from the space shuttle.

Relieve Overpressure

The atmospheric pressure is maintained below the design maximum internal-to-external differential pressure. Venting of atmosphere to space does not occur at less than 103.4 kPa (15.0 psid).

Equalize Pressure

The pressure differential between adjacent, isolated volumes at 103.4 kPa (775.7 mmHg, 15.0 psia) and 99 kPa (740 mmHg, 14.3 psia) can be equalized to less than 0.07 kPa (0.5 mmHg, 0.01 psia) within 3 min.

Respond to Rapid Decompression

A rapid decompression event can be detected prior to the total pressure decreasing by 3.4 kPa (0.5 psia) based on a hole size 1.27 to 5.08 cm (0.5 to 2.0 in) in diameter.

The USOS, except for the affected element, can be repressurized from a minimum total pressure of 86.1 kPa (12.5 psia) to a total pressure of 95.8 to 102.7 kPa (13.9 to 14.9 psia) and a ppO_2 of 19.5 to 23.1 kPa (2.83 to 3.35 psia) within 75 hr, when supplied with gaseous O_2 and N_2.

Respond to Hazardous Atmosphere

Combustion products can be detected over the ranges specified in table 7. The atmosphere of any pressurized volume can be vented to space to achieve an atmospheric pressure less than 2.8 kPa (20.7 mmHg, 0.4 psia) within 24 hr. PBA's provide 1 hr of continuous emergency supply of O_2 for each crew member through O_2 ports or 15 min with emergency O_2 tanks. Any single affected element can be repressurized from space vacuum to a total pressure of 95.8 to 98.6 kPa (13.9 to 14.3 psia) and a ppO_2 of 16.4 to 23.1 kPa (2.38 to 3.35 psia) within 75 hr.

TABLE 7.—*Combustion product detection ranges (S683–29573D, SSP41000B).*

Compound	Range (ppm)
Carbon Monoxide (CO)	5 to 400
Hydrogen Chloride (HCl)	1 to 100
Hydrogen Cyanide (HCN)	1 to 100
Hydrogen Fluoride (HF)/Carbonyl Fluoride (COF_2)	1 to 100

Control Atmospheric Temperature

The atmospheric temperature in the cabin aisleway is maintained within the range of 18.3 to 29.4 °C (65 to 85 °F). During campout, the AL atmospheric temperature is maintained between 18.3 to 29.4 °C (±1 °C) (65 and 85 °F (±2 °F)) and is selectable by the crew.

Control Atmospheric Moisture

The atmospheric relative humidity in the cabin aisleway is maintained within the range of 25 to 70 percent and the dewpoint within the range of 4.4 to 15.6 °C (40 to 60 °F). Humidity condensate from the Hab, Lab, and AL is delivered to the wastewater bus at a rate up to 1.45 kg (3.2 lb/hr) and a pressure up to 55 kPa (8 psig).

Circulate Atmosphere Intramodule

The effective atmospheric velocity in the cabin aisleway is maintained within the range of 0.08 to 0.20 m/sec (15 to 40 fpm), with a minimum velocity of 0.05 m/sec (10 fpm) when supporting high heat load conditions in attached modules.

Circulate Atmosphere Intermodule

Atmosphere is exchanged with adjacent, attached pressurized segments at a rate of 63.7 to 68.4 L/sec (135 to 145 ft^3/min).

Control Carbon Dioxide

The $ppCO_2$ is maintained within the range shown in figure 93. The $ppCO_2$ is monitored over a range of 0.0 to 2.0 kPa (0.0 to 15.0 mmHg, 0.00 to 0.29 psia) with an accuracy of ±1 percent of full scale.

Control Gaseous Contaminants

Atmospheric trace gas contaminants that are generated during normal operations are maintained at levels below the 180-day SMAC levels and the removed gases are disposed of. The SMAC levels are listed in table 8. Trace gases are monitored in the atmosphere at the detection limit and accuracy as defined in table 9. (Trace gas monitoring is the responsibility of the CHeCS.)

Control Airborne Particulate Contaminants

Airborne particulates are removed so as to have no more than 0.05 mg/m^3 (100,000 particles per ft^3) with peak concentrations less than 1.0 mg/m^3 (2 million particles/ft^3) for particles from 0.5 to 100 microns in diameter.

Control Airborne Microbial Growth

The daily average concentration of airborne microorganisms is limited to less than 1,000 CFU/m^3. The atmosphere is monitored for bacteria, yeast, and molds, with a sampling volume from 1 to 1,000 L of atmosphere. On surfaces (the source of airborne microorganisms) the acceptable ranges of bacteria and fungi are 0 to 40 CFU/cm^2 and 0 to 4 CFU/cm^2, respectively. Samples are collected once per month and during crew exchange (SSP 41000B, p. 232).

Respond to Fire

The general philosophy regarding responding to a fire is to provide for maximum crew flexibility to fight a localized fire without jeopardizing other modules or segments of the *ISS*. This approach can be summarized in the following steps:

- Mitigate fire by controlling the sources of ignition, fuel, and oxidizer. The ignition source is controlled by material control and design for proper wiring, overcurrent protection, etc. The fuel is controlled by stringent flammability requirements. The oxidizer is controlled by reliability requirements to preclude O_2 leakage.

- Detect a fire at its early stages at the source in order to contain and stop propagation of fire byproducts to the larger habitable volumes.

- Suppress and fight a fire at the source when the fire is small and easily contained.

- Engage the crew in real-time assessment and fire fighting activities.

The following requirements must be met:

- The crew must be able to initiate notification of a fire event within 1 min after detection.
- Isolation of a fire event must not cause loss of functionality that may create a catastrophic hazard.
- Access to apply fire suppressant must be provided at each enclosed location containing a potential fire source.
- The fire suppressant must be compatible with the *ISS* ECLS hardware, not exceed a partial pressure of 34.2 mmHg in any isolated element, and be noncorrosive.
- Fire suppressant byproducts must be compatible with the *ISS* ECLS contamination control capability.
- Fixed fire suppression, where installed, must incorporate a disabling feature to prevent inadvertent activation during maintenance. (Fixed fire suppression is not used on the *ISS*.)
- One PBA and one PFE must be located in elements with accessible interior length of ≤ 7.3 m (24 ft). Where the element exceeds 7.3 m (24 ft) in accessible interior length, a set of PBA's and PFE's must be located within 3.7 m (12 ft) of each end of the element. At least one PBA must be located within 0.91 m (3 ft) of each PFE.
- The *ISS* must confirm a fire event condition prior to any automated isolation or suppression. Confirmation consists of at least two validated indications of fire/smoke from a detector.
- Onboard verification of suppressant availability must be provided.

The capability is required to detect a fire event in accordance with the selection criteria in figures 14, 15, and 16. Isolation of the fire (by removal of power and forced ventilation in the affected location) will occur within 30 sec of detection. Detection of a fire will initiate a Class I alarm and a visual indication of the fire event will be activated. Forced ventilation between modules will stop within 30 sec of annunciation of a Class I fire alarm. PBA's and PFE's are provided.

TABLE 8.—*U.S. spacecraft maximum allowable concentrations of gaseous contaminants (S683–29573D, SSP41000B).*

	Potential Exposure Period				
Chemical (mg/m^3)	**1 hr**	**24 hr**	**7 days**	**30 days**	**180 days**
Acetaldehyde	20	10	4	4	4
Acrolein	0.2	0.08	0.03	0.03	0.03
Ammonia	20	14	7	7	7
Carbon Dioxide	10	10	5.3	5.3	5.3
Carbon Monoxide	60	20	10	10	10
1,2-Dichloroethane	2	2	2	2	1
2-Ethoxyethanol	40	40	3	2	0.3
Formaldehyde	0.5	0.12	0.05	0.05	0.05
Freon™113	400	400	400	400	400
Hydrazine	5	0.4	0.05	0.03	0.005
Hydrogen	340	340	340	340	340
Indole	5	1.5	0.25	0.25	0.25
Mercury	0.1	0.02	0.01	0.01	0.01
Methane	3,800	3,800	3,800	3,800	3,800
Methanol	40	13	9	9	9
Methyl Ethyl Ketone	150	150	30	30	30
Methyl Hydrazine	0.004	0.004	0.004	0.004	0.004
Dichloromethane	350	120	50	20	10
Octamethyltrisiloxane	4,000	2,000	1,000	200	40
2-Propanol	1,000	240	150	150	150
Toluene	60	60	60	60	60
Trichloroethylene	270	60	50	20	10
Trimethylsilanol	600	70	40	40	40
Xylene	430	430	220	220	220

TABLE 9.—*Trace gas detection limit (S683–29573D, SSP41000B).*

Compound	Detection Limits (mg/cm^3)	Compound	Detection Limits (mg/cm^3)
Methanol	0.5	Ethanol	5.0
2-Propanol	5.0	2-Methyl-2-Propanol	5.0
N-Butanol	5.0	Ethanal (Acetaldehyde)	0.5
Benzene	0.1	Xylenes	10.0
Methyl Benzene (Toluene)	3.0	Dichloromethane	0.5
Dichlorodifluoromethane (Freon™ 12)	10.0	Chlorodifluoromethane (Freon™ 22)	5.0
Trichlorofluoromethane (Freon™ 11)	10.0	1,1,1-Trichloroethane	1.0
1,1,2-Trichloro-1,1,2-Trifluoroethane (Freon™ 113)	5.0	N-Hexane	5.0
N-Pentane	10.0	Methane	180.0
2-Methyl-1,3-Butadiene	10.0	2-Propanone (Acetone)	1.0
2-Butanone	3.0	Hydrogen	10.0
Carbon Monoxide	2.0	Hexamethylcyclotrisiloxane	10.0
Trimethylsilanol	3.0	2-Butoxyethanol	1.0
Trifluorobromomethane (Halon™ 1301)	10.0	Carbonyl Sulfide	0.5
Acetic Acid	0.5	4-Hydroxy-4-Methyl-2-Pentanone	1.0
Accuracy			
Concentration	**Percent Accuracy***	**Concentration**	**Percent Accuracy***
5 to 10 mg/m^3	±20	0.5 to 2 mg/m^3	±40
2 to 5 mg/m^3	±30	<0.5 mg/m^3	±50

*Percent accuracy = ((measured concentration–actual concentration)/(measured concentration)) × 100

The PBA's provide 1 hr of O_2 through O_2 ports. Fires will be suppressed by PFE's within 1 min of suppressant discharge. When initiated by the crew or Ground Control, the USOS will vent the atmosphere of any pressurized volume to space to achieve an O_2 concentration below 6.9 kPa (1.0 psia) within 10 min. The capability to restore the habitable environment after a fire event is present.

Accommodate Crew Hygiene and Wastes

Facilities are provided for personal hygiene and collection, processing, and disposal of crew metabolic waste. The wastes include menstrual discharge and associated absorbent material; emesis; fecal solids, liquids, gases, and particulates; urine and associated consumable material; soap, expectorants, hair, nail trimmings, and hygiene water; and externally collected crew wastes.

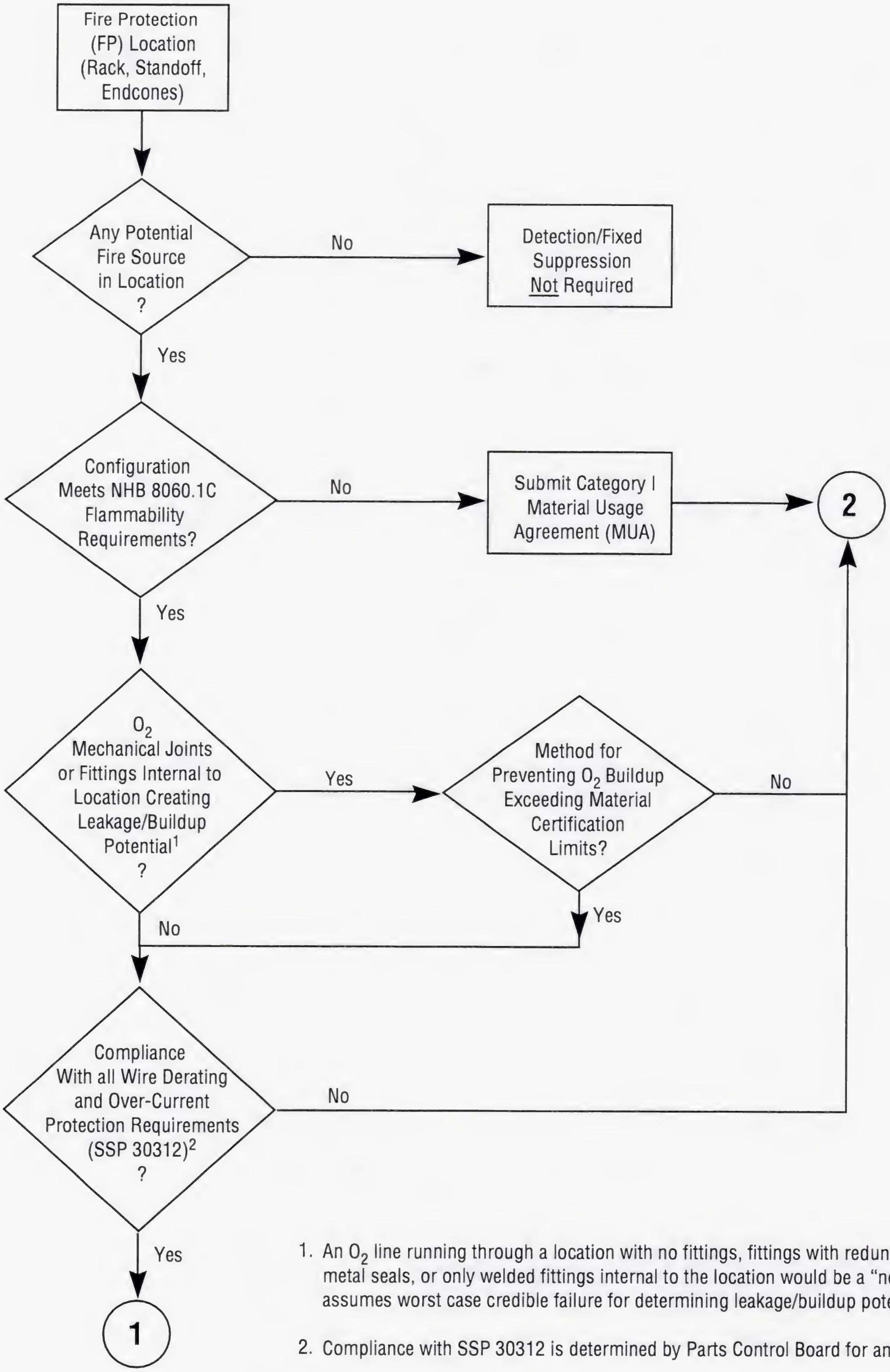
Facilities are provided for personal grooming, including skin care, shaving, hair grooming, and nail trimming. Simultaneous whole body skin and hair cleaning are accommodated. Facilities accommodate washing of selected body areas as required for the following:

- After urination and defecation
- After exercise
- During medical exams and health maintenance
- Before and after experimentation or other activities requiring specialized washing
- Before and after meals.

Provide Water for Crew Use

Water provided for crew use is of potable quality, as indicated in table 10. An average of 2.8 kg/person/day (6.2 lb/person/day) of potable water for food rehydration, consumption, and oral hygiene is provided for up to six people. Up to 5.15 kg/person/day (11.35 lb/person/day) of potable water can be provided in any 24-hr period. Fuel-cell water from the space shuttle is provided for potable use and the USOS provides storage for 408 kg (900 lb) of fuel cell water. In addition, the *ISS* provides up to 3.34 kg/day (7.35 lb/day) of potable water for life science experiments.

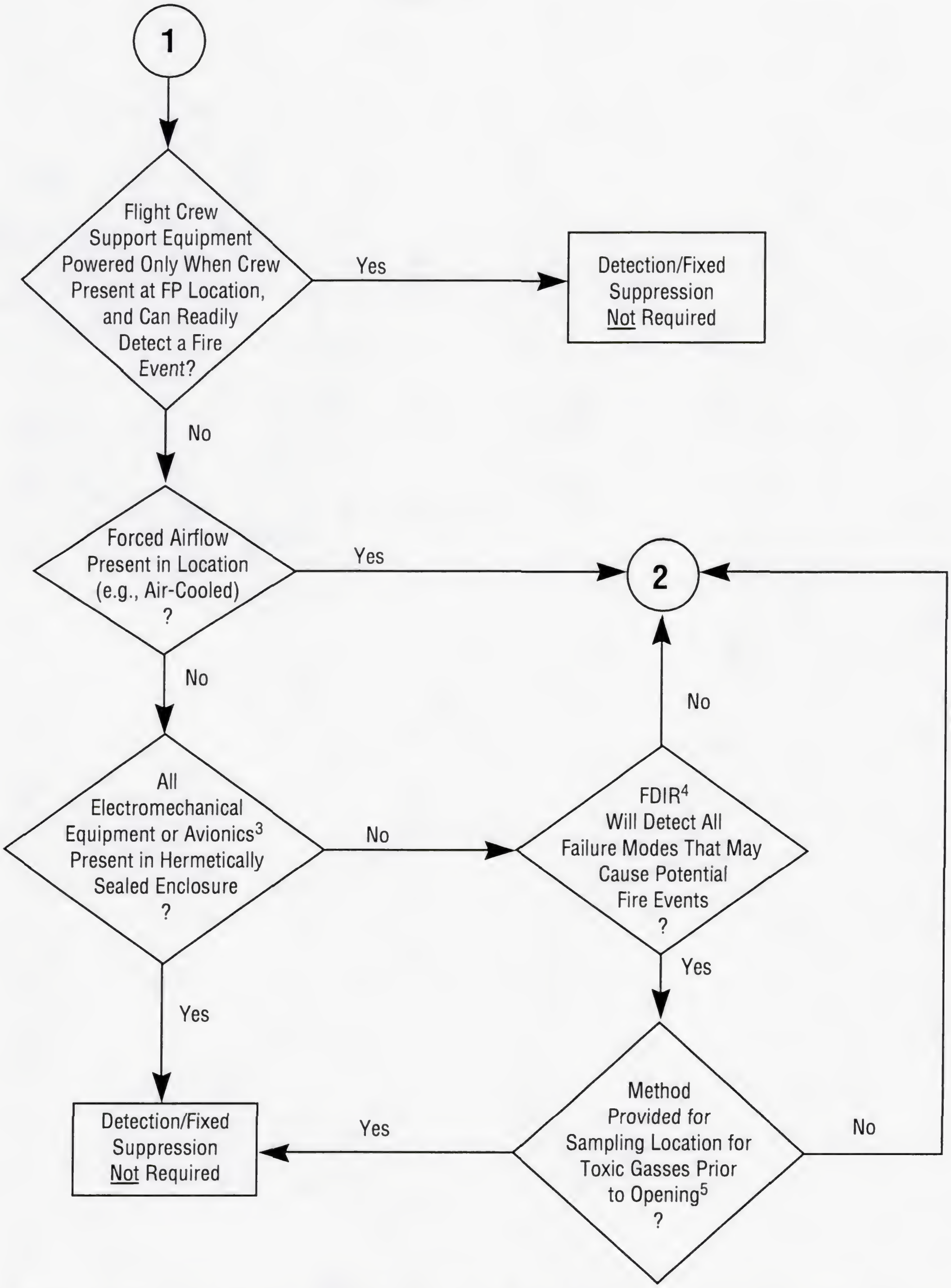
An average of 6.8 kg/person/day (15.0 lb/person/day) of hygiene water is provided. Up to 7.3 kg/person (16.0 lb/person) of hygiene water can be provided in any 24-hr period. Wastewater is collected, processed, and returned to the water subsystem. Urine is collected and processed at an average rate of 1.56 kg/person/day (3.43 lb/person/day).



1. An O_2 line running through a location with no fittings, fittings with redundant seals, metal seals, or only welded fittings internal to the location would be a "no." Also assumes worst case credible failure for determining leakage/buildup potential.

2. Compliance with SSP 30312 is determined by Parts Control Board for any deviations.

Figure 14.—USOS fire protection selection criteria (D684–10210–01).

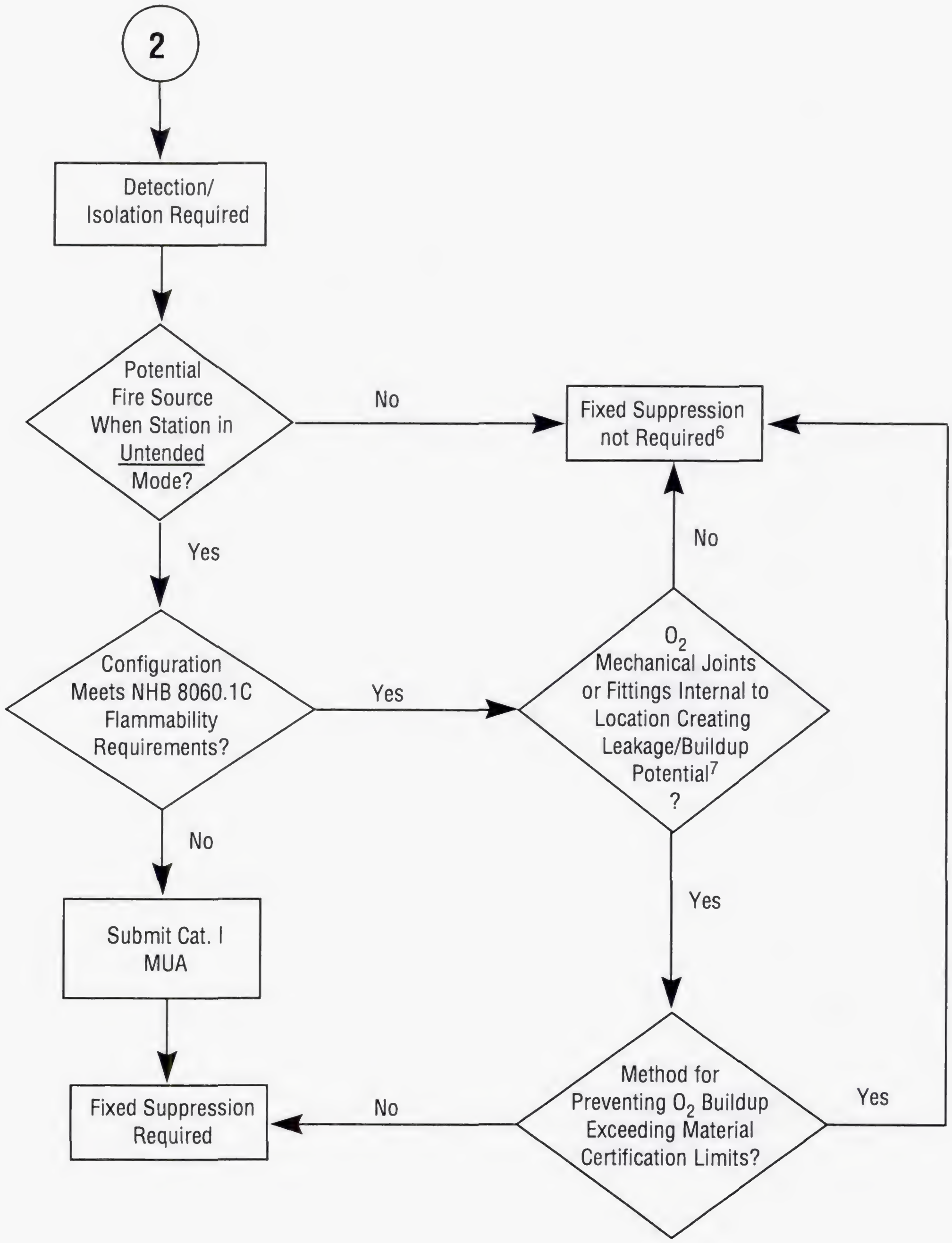


3. Avionics refers to any electrical equipment or components other than power/data connectors, cables, lines, or wires (e.g., card-mounted electronic components). Electromechanical equipment refers to any motors, pumps, etc.

4. FDIR must be sufficient to alert the crew to failure modes of the equipment, not in hermetically sealed enclosures, which could cause a fire event. Notification of loss of function satisfies the FDIR requirements. Electrical equipment and wiring having two upstream devices to detect and isolate over-current and short circuiting conditions meet the FDIR requirements.

5. Sampling is intended to allow the crew to avoid opening a location which may contain a buildup of hazardous offgassing. Sampling through a PFE supression port using the GFE manual sampling equipment satisfies this requirement.

Figure 15.—USOS fire protection selection criteria (D684–10210–01) (continued).



6. Based on capability of crew to perform suppression via PFE's for locations which will be powered only when the *ISS* is tended. When the *ISS* is untended the material control and no O_2 leakage/buildup potential will prevent fire from propagating.

7. An O_2 line running through a location with no fittings, fittings with redundant seal, or only welded fittings internal to the location would be a “no.” Assumes worst case credible failure.

FIGURE 16.—USOS fire protection selection criteria (D684–10210–01) (continued).

Supply Water for Payloads

The USOS provides 2.2 kg/day (4.8 lb/day) of potable water to payload users, dispensed from a central location. In addition, 3.33 kg/day (7.35 lb/day) of potable water, dispensed from a central location, is provided to support life science experiments. The payload users or experimenters are responsible for providing the means of transporting the water from the dispenser to the site of use.

Supply Vacuum Services to User Payloads

Vacuum resource and waste gas vent services are provided to user payloads.

Support Denitrogenation

The USOS provides for denitrogenation for two people preparing for an EVA. This consists of a 12-hr campout in the AL at 70.3 kPa (10.2 psia) ±1.4 kPa (0.2 psia) with 27 to 30 percent O_2. Additionally, the capability for an in-suit prebreathe period of 40 min to 4 hr is provided. The capability for an in-suit purge for a minimum of 12 min prior to an EVA is also provided. Both U.S. and Russian protocols are followed. The United States supplies prebreathe O_2 for 13 EVA's every 90 days. At least 70 percent of the atmosphere is recovered during an EVA, including preparation for the EVA.

Support Service and Checkout

This capability is provided in the AL. (Details are not presently available.)

Support Station Egress

This capability is provided in the AL. (Details are not presently available.)

Support Station Ingress

This capability is provided in the AL. (Details are not presently available.)

Distribute Gases to User Payloads

N_2 is provided for payloads. (Details are not presently available.)

3.3.3 APM ECLS Capabilities

The APM ECLS capabilities are:

Control Total Atmospheric Pressure

Total atmospheric pressure is monitored, and positive and negative pressure relief is present.

Control Oxygen Partial Pressure

This capability is not required in the APM.

Relieve Overpressure

The atmospheric pressure is maintained to less than the design maximum internal-to-external differential pressure. Venting of atmosphere to space does not occur at less than 103.4 kPa (15.0 psid).

Equalize Pressure

The pressure differential between adjacent, isolated volumes at 103.4 kPa (775 mmHg, 15.0 psia) and 98.6 kPa (740 mmHg, 14.3 psia) can be equalized to less than 0.07 kPa (0.5 mmHg, 0.01 psid) within 3 min.

Respond to Rapid Decompression

The differential pressure of depressurization, repressurization, and the depressurized condition can be tolerated without resulting in a hazard or failure propagation.

Respond to Hazardous Atmosphere

The first response is to don PBA's which have a 15-min supply of air or O_2 for at least two people. The capability is present to vent the atmosphere to space to achieve an atmospheric pressure less than 2.76 kPa (20.7 mmHg, 0.4 psia) within 24 hr. The atmosphere can be repressurized from space vacuum to a total pressure of 95.8 to 98.6 kPa (13.9 to 14.3 psia) and ppO_2 of 16.4 to 23.1 kPa (2.38 to 3.35 psia) within 75 hr with O_2 and N_2 from the USOS, as specified in SSP 41150.

Control Atmospheric Temperature

The atmospheric temperature in the cabin aisleway is maintained within the range of 18.3 to 26.7 °C (65 to 80 °F). The atmospheric temperature setpoint is selectable by the flight or ground crew and the setpoint can be controlled within ±1 °C (±2 °F).

TABLE 10.—*USOS water quality requirements (SSP 41162B).*

Parameters	Potable Water Specifications (4)
Physical	
Total Solids	100 mg/L
Color True	15 Pt/Co Units
Taste	3 TTN
Odor	3 TON
Particulates	40 microns (max size)
pH	6.0 to 8.5
Turbidity	1 NTU
Dissolved Gas	(1) (free at 37 °C)
Free Gas	(1) (STP)
Aesthetics	
CO_2	15 mg/L
Microbial	
Bacteria/Fungi	100 CFU/100 mL
Total Coliform	<1 CFU/100 mL
Virus	<1 CFU/100 mL
Organic Parameters (2)	
Total Acids	500 µg/L
Cyanide	200 µg/L
Halogenated Hydrocarbons	10 µg/L
Total Phenols	1 µg/L
Total Alcohols	500 µg/L
Total Organic Carbon (TOC)	500 µg/L
Uncharacterized TOC (UTOC) (3)	100 µg/L

Parameters	Potable Water Specifications (4)
Inorganic Constituents	
Ammonia	0.5 mg/L
Arsenic	0.01 mg/L
Barium	1.0 mg/L
Cadmium	0.005 mg/L
Calcium	30 mg/L
Chlorine (Total—Includes Chloride)	200 mg/L
Chromium	0.05 mg/L
Copper	1.0 mg/L
Iodine (Total—Includes Organic Iodine)	15 mg/L
Iron	0.3 mg/L
Lead	0.05 mg/L
Magnesium	50 mg/L
Manganese	0.05 mg/L
Mercury	0.002 mg/L
Nickel	0.05 mg/L
Nitrate (NO_3-N)	10 mg/L
Potassium	340 mg/L
Selenium	0.01 mg/L
Silver	0.05 mg/L
Sulfate	250 mg/L
Sulfide	0.05 mg/L
Zinc	5 mg/L
Bactericide	
Residual Iodine (Minimum)	1 mg/L
Residual Iodine (Maximum)	4 mg/L

Notes:
(1) No detectable gas using a volumetric gas versus fluid measurement system—excludes CO_2 used for aesthetic purposes.
(2) Each parameter/constituent maximum contamination level (MCL) must be considered individually and independently of others.
(3) UTOC equals TOC minus the sum of analyzed organic constituents expressed in equivalent TOC.
(4) MCL.

Control Atmospheric Moisture

The atmospheric dewpoint is maintained within the range of 4.4 to 15.6 °C (40 to 60 °F) and relative humidity in the cabin aisleway within the range of 25 to 70 percent. Water condensed from the atmosphere is delivered to the USOS in accordance with SSP 41150.

Circulate Atmosphere Intramodule

The effective atmospheric velocity in the cabin aisleway is maintained within the range of 0.08 to 0.2 m/sec (15 to 40 fpm).

Circulate Atmosphere Intermodule

IMV is performed by the IMV fan in Node 2 (SSP 41000B, p. 46) at a rate of 64 to 68 L/sec (135 to 145 cfm).

Control CO_2

This capability is provided by the USOS.

Control Gaseous Contaminants

Primary control is provided by the USOS. The capability to initiate depressurization of the APM is provided.

Respond to Fire

The capability to detect a fire event in accordance with the selection criteria in figures 14, 15, and 16 is provided. Isolation of the fire (by removal of power and forced ventilation in the affected location) will occur within 30 sec of detection. Forced ventilation between modules will stop within 30 sec of annunciation of a Class I fire alarm. PBA's and PFE's are provided.

Detection of a fire will initiate a Class I alarm and a visual indication of the fire event will be activated. The PFE's will suppress a fire within 1 min of suppressant discharge by reducing the oxygen concentration to less than 10.5 percent. When initiated by the crew or Ground Control, the APM will vent the atmosphere to space to achieve an oxygen concentration less than 6.9 kPa (1.0 psia) within 10 min. The capability to restore the habitable environment after a fire event is present.

Control Airborne Particulate Contaminants

The average atmospheric particulate level complies with class 100,000 clean room requirements.

Control Airborne Microbial Growth

The daily average concentration of airborne micro-organisms is limited to less than 1,000 CFU/m^3.

Accommodate Crew Hygiene and Wastes

This capability is provided by the USOS.

Provide Water for Crew Use

This capability is provided by the USOS.

Supply Water for Payloads

This capability is not required in the APM.

Supply Vacuum Services to User Payloads

Vacuum resource and waste gas vent services are provided to user payloads.

Support Denitrogenation

This capability is not required in the APM.

Support Service and Checkout

This capability is not required in the APM.

Support Station Egress

This capability is not required in the APM.

Support Station Ingress

This capability is not required in the APM.

Distribute Gases to User Payloads

Nitrogen is provided to user payloads.

3.3.4 JEM ECLS Capabilities

The JEM ECLS capabilities are:

Control Total Pressure

This capability is provided by the USOS.

Control Oxygen Partial Pressure

This capability is provided by the USOS.

Relieve Overpressure

The atmospheric pressure is maintained to less than the design maximum internal-to-external differential pressure. Venting of atmosphere to space does not occur at less than 103.4 kPa (15.0 psid).

Equalize Pressure

The pressure differential between adjacent, isolated volumes at 103.4 kPa (775 mmHg, 15.0 psia) and 98.6 kPa (740 mmHg, 14.3 psia) can be equalized to less than 0.07 kPa (0.5 mmHg, 0.01 psia) within 3 min.

Respond to Rapid Decompression

The differential pressure of depressurization, repressurization, and the depressurized condition can be tolerated without resulting in a hazard or failure propagation.

Respond to Hazardous Atmosphere

The first response is to don PBA's which have a 15-min supply of air or O_2 for at least two people. The capability is present to vent the atmosphere to space to achieve an atmospheric pressure less than 2.76 kPa (20.7 mmHg, 0.4 psia) within 24 hr. The atmosphere can be repressurized from space vacuum to a total pressure of

95.8 to 98.6 kPa (13.9 to 14.3 psia) and a ppO_2 of 16.4 to 23.1 kPa (2.38 to 3.35 psia) within 75 hr, with O_2 and N_2 supplied from the USOS, as specified in SSP 41151, paragraphs 3.2.4.3.5 and 3.2.4.4.5.

Control Atmospheric Temperature

The atmospheric temperature in the cabin aisleway and laboratory aisleway is maintained within the range of 18.3 to 26.7 °C (65 to 80 °F). The atmospheric temperature setpoint is selectable by the flight or ground crew and the setpoint can be controlled within ± 1 °C (± 2 °F) during normal operation at 18.3 to 26.7 °C (65 to 80 °F) for nominal loads or 21.1 to 26.7 °C (70 to 80 °F) for high heat loads. Temperature selectability is not required during peak-heat-load conditions.

Control Atmospheric Moisture

The atmospheric relative humidity in the cabin aisleway is maintained within the range of 25 to 70 percent, and the dewpoint within the range of 4.4 to 15.6 °C (40 to 60 °F). Water condensed from the atmosphere is delivered to the USOS in accordance with SSP 41151, paragraph 3.2.4.2.4.

Circulate Atmosphere Intramodule

The effective atmosphere velocities in the cabin aisleway is maintained within the range of 0.08 to 0.2 m/sec (15 to 40 fpm).

Circulate Atmosphere Intermodule

Atmosphere is exchanged with the USOS as specified in SSP 41151, paragraph 3.2.4.1 (at a rate of 63.7 to 68.4 L/sec (135 to 145 ft^3/min)).

Control CO_2

This capability is provided by the USOS.

Control Gaseous Contaminants

This capability is provided by the USOS.

Control Airborne Particulate Contaminants

Airborne particulates are removed to have no more than 0.05 mg/m^3 (100,000 particles per ft^3) with peak concentrations less than 1.0 mg/m^3 (2 million particles/ft^3) for particles from 0.5 to 100 microns in diameter.

Control Airborne Microbial Growth

The daily average concentration of airborne microorganisms is limited to less than 1,000 CFU/m^3.

Respond to Fire

The capability to detect a fire event in accordance with the selection criteria in figures 14, 15, and 16 is provided. Isolation of the fire (by removal of power and forced ventilation in the affected location) will occur within 30 sec of detection. Forced ventilation between modules will stop within 30 sec of annunciation of a Class I fire alarm. PBA's and PFE's are provided.

Detection of a fire will initiate a Class I alarm and a visual indication of the fire event will be activated. The PFE's will suppress a fire within 1 min of suppressant discharge by reducing the oxygen concentration to less than 10.5 percent. When initiated by the crew or Ground Control, the JEM will vent the atmosphere to space to achieve an oxygen concentration less than 6.9 kPa (1.0 psia) within 10 min. The capability to restore the habitable environment after a fire event is present.

Accommodate Crew Hygiene and Wastes

This capability is provided by the USOS.

Provide Water for Crew Use

This capability is provided by the USOS.

Supply Water for Payloads

This capability is provided by the USOS.

Supply Vacuum Services to User Payloads

Vacuum resource and waste gas vent services are provided to user payloads.

Support Denitrogenation

This capability is not required in the JEM.

Support Service and Checkout

This capability is not required in the JEM.

Support Station Egress

This capability is not required in the JEM.

Support Station Ingress

This capability is not required in the JEM.

Distribute Gases to User Payloads

Nitrogen and other gases are provided to user payloads.

3.3.5 MPLM ECLS Capabilities

The MPLM ECLS capabilities are:

Control Total Pressure

This capability is provided by the USOS.

Control Oxygen Partial Pressure

This capability is provided by the USOS.

Relieve Overpressure

The atmospheric pressure is maintained to be less than the design maximum internal-to-external differential pressure. Venting of atmosphere to space does not occur at less than 102.0 kPa (14.8 psid) when the MPLM is isolated.

Equalize Pressure

The pressure differential between adjacent, isolated volumes at 103.4 kPa (775 mmHg, 15.0 psia) and 98.6 kPa (740 mmHg, 14.3 psia) can be equalized to less than 0.07 kPa (0.5 mmHg, 0.01 psid) within 3 min. The MPLM will equalize the pressure differential between adjacent, isolated volumes to less than 0.07 kPa (0.01 psid) with the MPLM at space vacuum, and the adjoining isolated volume at 103.4 kPa (15.0 psia) within 75 hr.

Respond to Rapid Decompression

The differential pressure of depressurization, repressurization, and the depressurized condition can be tolerated without resulting in a hazard or failure propagation.

Respond to Hazardous Atmosphere

The atmosphere can be vented to space to achieve an atmospheric pressure less than 2.8 kPa (0.4 psia) within 24 hr.

Control Atmospheric Temperature

This capability is provided by the USOS.

Control Atmospheric Moisture

This capability is provided by the USOS which maintains the relative humidity in the MPLM in the range of 25 to 70 percent and the dewpoint in the range of 4.4 to 15.6 °C (40 to 60 °F).

Circulate Atmosphere Intramodule

The effective atmosphere velocities in the cabin aisleway are maintained within the range of 0.08 to 0.2 m/sec (15 to 40 fpm).

Circulate Atmosphere Intermodule

Atmosphere is exchanged with the USOS as specified in SSP 42007 (at a rate of 63.7 to 68.4 L/sec (135 to 145 ft^3/min).

Control CO_2

This capability is provided by the USOS.

Control Gaseous Contaminants

This capability is provided by the USOS.

Control Airborne Particulate Contaminants

This capability is provided by the USOS.

Control Airborne Microbial Growth

This capability is provided by the USOS.

Respond to Fire

The capability to detect a fire event in accordance with the selection criteria in figures 14, 15, and 16 is provided. A "detected smoke" signal will be sent to the USOS, which then will switch off power to the MPLM. Isolation of the fire (by removal of power and forced ventilation in the affected location) will occur within 30 sec of detection. Forced ventilation between modules will stop within 30 sec of annunciation of a Class I fire alarm. PBA's and PFE's are provided.

Detection of a fire will initiate a Class I alarm and a visual indication of the fire event will be activated. The PFE's will suppress a fire within one minute of suppressant discharge by reducing the oxygen concentration to less than 10.5 percent. When initiated by the crew or Ground Control, the MPLM will vent the atmosphere to space to achieve an O_2 concentration less than 6.9 kPa (1.0 psia) within 10 min.

Accommodate Crew Hygiene and Wastes

This capability is provided by the USOS.

Provide Water for Crew Use

This capability is provided by the USOS.

Supply Water for Payloads

This capability is provided by the USOS.

Supply Vacuum Services to User Payloads

This capability is not required in the MPLM.

Support Denitrogenation

This capability is not required in the MPLM.

Support Service and Checkout

This capability is not required in the MPLM.

Support Station Egress

This capability is not required in the MPLM.

Support Station Ingress

This capability is not required in the MPLM.

Distribute Gases to User Payloads

This capability is not required in the MPLM.

4.0 Integrated Operation

The ECLS systems in the USOS and the RS are physically separate, but during operation the hatches in the FGB are open, and there is atmospheric transfer between the segments. This atmospheric movement carries water vapor and other atmospheric constituents, which materially connect the ECLS systems. Therefore, in addition to integrating hardware and functions, it is necessary to integrate operation of the ECLS systems and the responsibilities for performing the necessary tasks.

Integrated operation involves connecting the different segments, determining operational considerations, and addressing integration concerns. At the time of writing, details of the integrated operation of the *ISS* are being resolved. The information presented here may change and, therefore, serves as examples of the integration concerns and responses.

4.1 Intermodule ECLSS Interfaces

Interfaces include those between the different segments and those between different components within a segment. Interfaces between segments or modules include structural/mechanical and utility connections consisting of electrical power, atmosphere, structural and mechanical loads, data, and commands. (Data and command interfaces with the controllers on Earth are not considered in this report.) Interfaces include atmospheric ducting between modules within a segment. Other examples are the interfaces between the PFE's and the racks that may be potential fire sources, and the connections for the PBA. The interfaces that relate to ECLS are discussed in the following paragraphs.

4.1.1 RS ECLS Interface With the USOS

Interfaces with the USOS through PMA–1 and Node 1 include:

IMV Supply and Return

Atmosphere flows between the RS and the USOS through the open hatches and ducts. Respirable air is supplied from the FGB at a temperature of 18.3 to 28 °C (65 to 82.4 °F), a flowrate between 60 to 70 L/sec (127 and 148 ft^3/min), and a dewpoint between 4.4 and 13.9 °C (40 and 57 °F).

Respirable air is returned to the FGB at a temperature of 18.3 to 29.4 °C (65 to 85 °F), a flowrate between 60 to 70 L/sec (127 and 148 ft^3/min), and a dewpoint between 4.4 and 14 °C (40 and 57.2 °F). (The maximum dewpoint temperature is based on analysis; the specified maximum is 15.6 °C (60 °F).)

Water Transfer

The transfer from the USOS to the RS of water condensed from atmospheric humidity is performed manually using portable tanks (едв containers).

4.1.2 RS-to-EVA ECLS Interface

The RS ECLS interfaces with the Orlan pressure suit for servicing and checkout during EVA preparation and support of the EVA crew during suited operations within the DC.

4.1.3 USOS to APM, JEM, and MPLM ECLS Interface

USOS interfaces with the APM and JEM (shown in figures 17 and 18, respectively) include electrical power, gaseous nitrogen, thermal energy, atmosphere, and water return to the USOS. The USOS-to-APM physical and functional interface requirements are described in SSP 41150. The USOS-to-JEM physical and functional interface requirements are defined in SSP 41151, and design implementations are described in SSP 42000. The interfaces between the MPLM and the USOS are defined in SSP 42007, and shown in figure 19.

ECLS interfaces with the USOS through Node 2 include:

Coolant Supply and Return

Low-temperature coolant for the ITCS is supplied from the USOS at 0.6 to 5.6 °C (33 to 42 °F) and returned to the USOS at 3.3 to 21 °C (38 to 70 °F), at a pressure of 124 to 689 kPa (1.24 to 6.9 bar, 18 to 100 psia) and at a flowrate of 0 to 0.063 kg/s (0 to 8.33 lb/min).

Heat Load

The maximum heat load exchanged between Node 2 and the APM is ±200 W for sensible heat with no latent heat transfer.

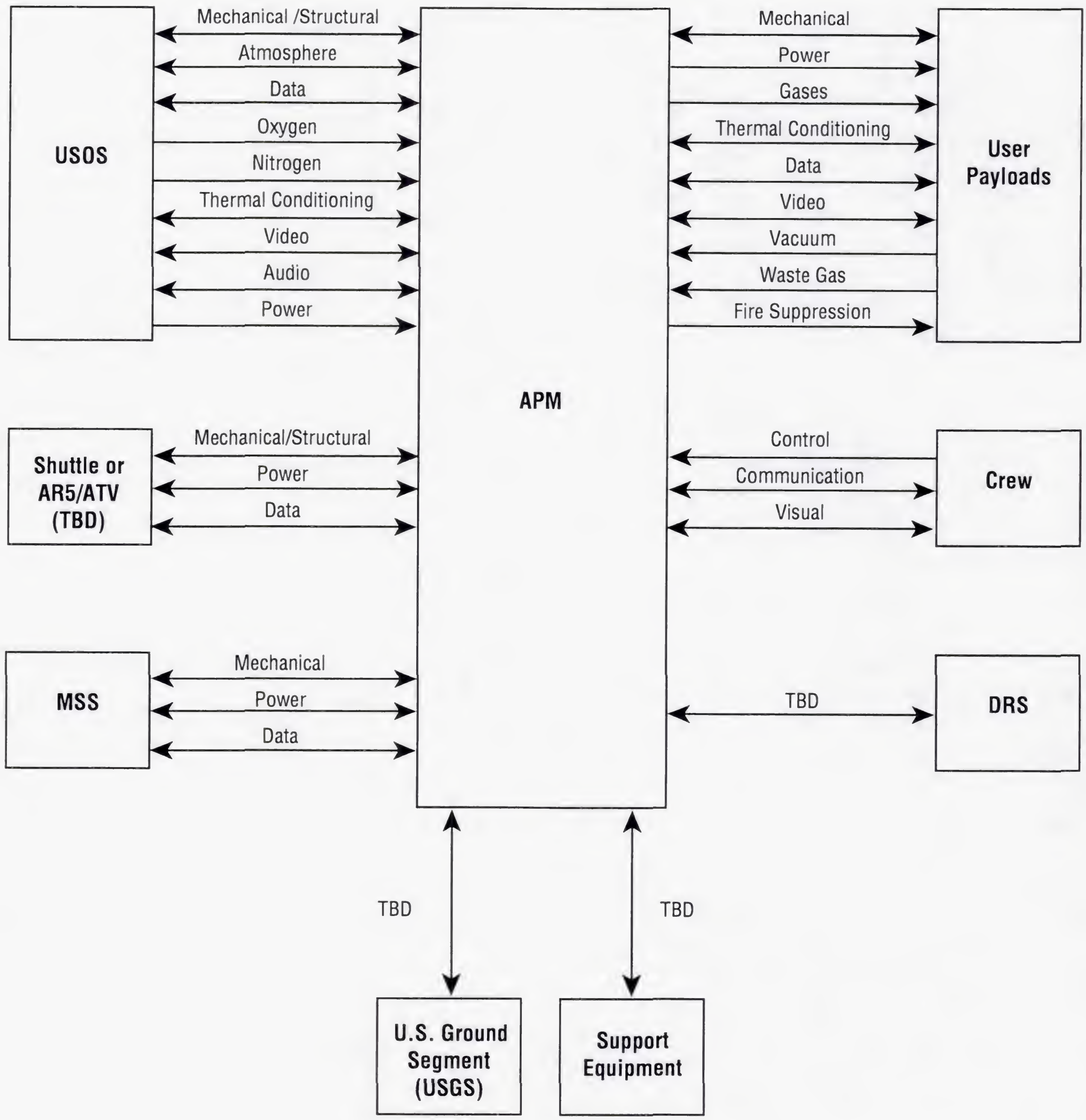


FIGURE 17.—APM external ECLS interfaces.

IMV Supply and Return

Respirable atmosphere is supplied from the USOS at 7.2 to 29 °C (45 to 85 °F), 95.8 to 104.8 kPa (13.9 to 15.2 psia), and at a flowrate between 3.8 and 4.1 m^3/min (135 and 145 ft^3/min). The supplied air has a dewpoint between 4.5 and 15.5 °C (40 and 60°F) and a relative humidity (RH) between 25 and 70 percent. RH's < 25 percent are allowed following repressurization. The maximum O_2 concentration is 24.1 percent by volume. The capability to supply IMV atmosphere during both open and closed hatch operations is present. The means to turn off and isolate IMV supply is also present.

By separate ducts, the USOS receives return IMV air at 95.8 to 104.8 kPa (13.9 to 15.2 psia) and at a flowrate between 64 and 68 L/sec (135 and 145 cfm). The capability to receive IMV atmosphere during both open and closed hatch operations is present. The means to turn off and isolate IMV return is also present.

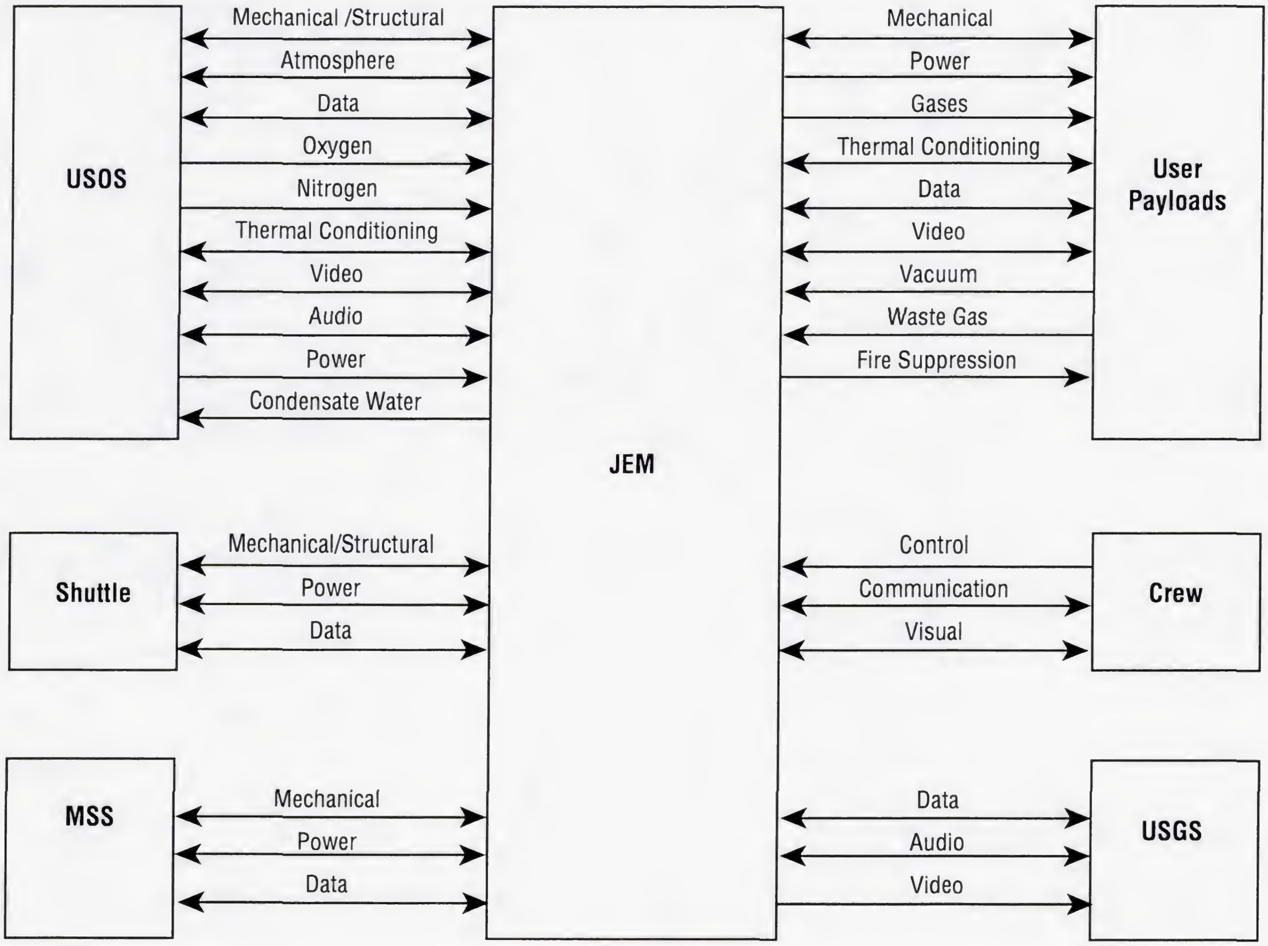


FIGURE 18.—JEM external ECLS interfaces.

Atmospheric Sampling

A separate internal line is used to acquire samples for monitoring (in the USOS) the major constituents and trace contaminants in the APM, JEM, and MPLM atmospheres. The maximum pressure loss in the sampling line on the APM side of the interface is 6.89 mbar (0.10 psia) at a flowrate of 400 scc/min.

Condensate Water

Condensate from the CHX in the APM and JEM is delivered to the water processor in the USOS via wastewater lines. The pressure in the wastewater lines can fluctuate between 0 and 0.6 bar (0 and 8 psia). The flowrate of condensate from the APM is a maximum of 1.4 kg/hr (3 lb/hr).

4.1.4 USOS-to-AL-to-EVA Interface

The AL interfaces with Node 1 of the USOS in accordance with SSP 41145. N_2 and O_2 leakage makeup gases are provided from the AL from storage tanks mounted externally, and water is provided for EVA from the USOS. The AL interfaces with EVA aids in accordance with SSP 30256–001, EVA Standard.

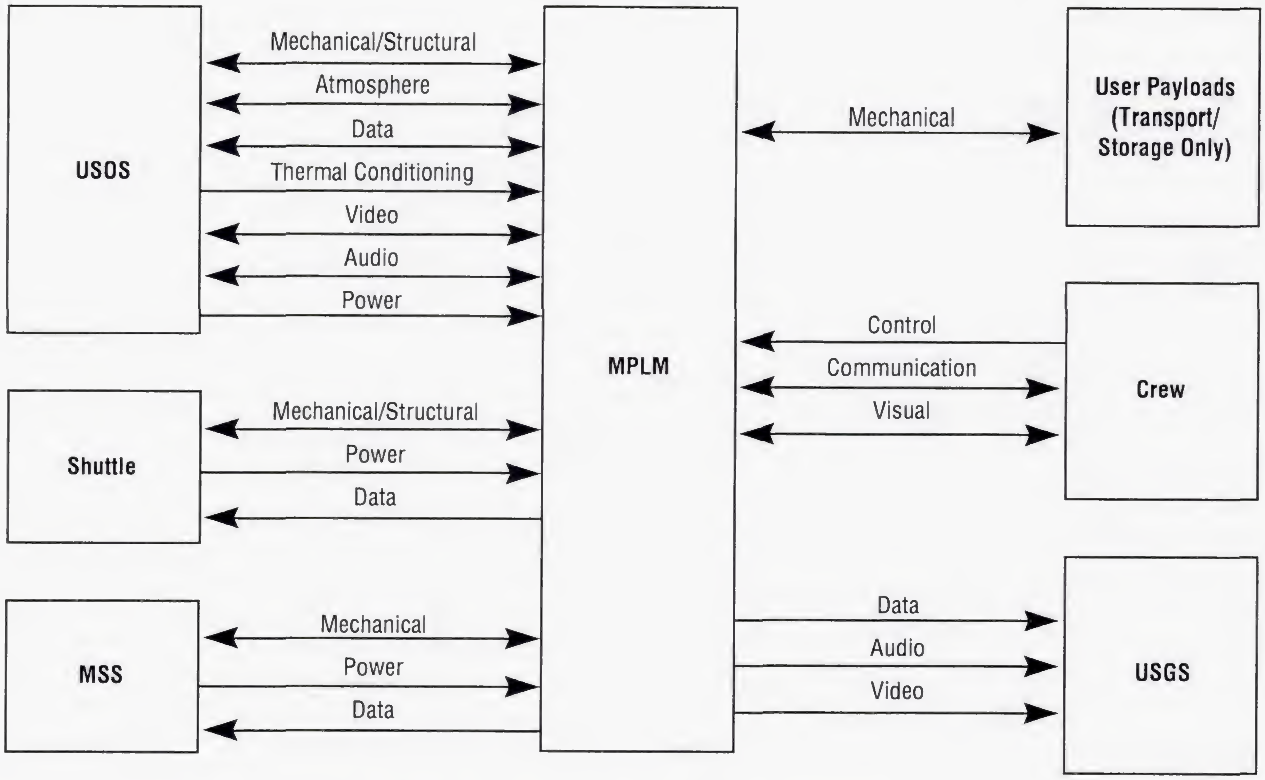


FIGURE 19.—MPLM external ECLS interfaces.

4.2 Operational Considerations

Operational considerations include the following:

Intermodule Ventilation

The present specification is for a dewpoint no greater than 15.6 °C (60 °F), but it is desirable to reduce that to 14 °C (57 °F) or less. The Russians would prefer to specify an 8 to 9 °C (46 to 48 °F) dewpoint to eliminate concern about window fogging and surface condensation. The lower the dewpoint, the better the reliability and redundancy. On the current *Mir* station the dewpoint is 11 °C (52 °F) normally, and 14 °C (57 °F) during crew exchange. The space shuttle has similar conditions. There is also a concern of trace contaminants entering the RS from the USOS and O_2 availability in the LSM, although it is not expected that the RS will get a large spike of trace contaminants from the USOS.

Atmospheric Gas Loss

The resupply atmosphere capacity on the Progress is insufficient so any additional amounts must be provided by the U.S. Any atmospheric losses above what the Progress can provide will come from the space shuttle or the AL O_2/N_2 tanks.

Atmosphere Control and Supply Issue

The ACS must also: (1) support O_2 metabolic needs of the 72 rodents (total of 1.08 kg/day (2.38 lb/day)) and (2) make up atmospheric losses due to crewlock losses, structural losses, and experiment losses. The USOS does not have the capability to provide this level of O_2. Furthermore, the RS may not have the capability based on power availability or water availability. The power availability concern may be corrected by delaying the requirements (i.e., phasing the requirements during assembly) or delaying the requirements until the power is available. If water availability is the only problem, a potential solution is to have the United States supplement the Russian water supply with space shuttle fuel-cell water.

For atmospheric loss makeup, the current RS resupply capability is 225 to 270 kg/yr (102 to 122 lb/yr), which is delivered by the Progress. The USOS will make up any of the shortfall, and the space shuttle will be the delivery vehicle. This option implies that the Russian O_2 generator is operating at 100 percent. In other words, the Progress tanks will be filled with N_2 only, and O_2 is supplied solely by the Russian O_2 generator.

Research Animals

Research animals on the USOS are phased in three steps: 24 rodents by 2001 (UF–5), 48 rodents by 2002 (UF–6), and 72 rodents by Assembly Complete (AC). The ECLS system is sized to handle the full animal load but the water balance is not completely defined. In principle there is an agreement to transfer water, but no details about how to do it. Some remaining issues to be addressed are:

- On the U.S. side:
  - Have a good understanding of the phasing of the requirements, especially the payload animal requirements.
  - Once this is understood, review the power profile to determine if the requirements are achievable.
  - If power is available, then determine if sufficient water is available.
  - If insufficient water is available, then determine if there is a way to store and transfer space shuttle fuel-cell water to the RS.
- On the Russian side:
  - Using the power availability, determine if the O_2 generator capability can meet the additional requirements.
  - Review the Russian water balance to determine if space shuttle fuel-cell water transfer is required.

Water Balance

The material connection of the USOS and RS affects such factors as the water balance between the segments, due to different specified maximum dewpoints—15.6 °C (60 °F) for the USOS and 13.9 °C (57 °F) for the RS—and differences in the ways that the U.S. and Russian humidity control equipment operates. For example, for a three-person crew the U.S. THC maintains the ppH_2O at about 1.1 kPa (8 mmHg), whereas the Russian condensate collection device does not operate until the ppH_2O reaches 1.3 to 1.6 kPa (10 to 12 mmHg). The U.S. THC operates essentially continuously, whereas the Russian condensate collection device operates for 6 to 8 hr per 24-hr period. The Russians also separate humidity control and temperature control, whereas the U.S. THC combines these functions. Because of these operational differences, the USOS collects most of the condensate.

The water balance between the RS and the USOS is also affected by the assembly sequence. Prior to Russian LSM activation, the *ISS* has a three-person crew on board. The SM provides condensate collection and processing. The Progress provides water makeup, O_2 supply, and EVA support. The USOS has a low-temperature loop as soon as the Lab is activated, so the Lab collects condensate from the beginning, and, currently, there is no means to transfer this condensate water to the RS, thus an imbalance in the water supply results.

After the Russian LSM is installed, as shown in figure 20, the cooling and humidity removal loads change somewhat. This affects the water balance, but the way in which the water balance is affected depends on the allowable dewpoints and flowrates of ventilation between the modules. The return air from the USOS has a dewpoint of 4.4 to 15.6 °C (40 to 60 °F), but nominally close to 10 °C (50 °F) and typically 7.2 °C (45 °F). At AC there is a six-person crew, with a greater humidity load due to respiration and perspiration.

The present RS water usage philosophy is similar to that on the *Mir*. On the *Mir*, only 75 percent of the O_2 supply is generated by water electrolysis (due to power constraints) and 25 percent is provided by solid perchlorate and other O_2 sources. On the *ISS*, if there are no power constraints, 100 percent of the O_2 supply is generated by water electrolysis. If there is a power constraint, then the O_2 generation is at 75 percent. The first case uses five Progress missions with a 200 L (435 lb) shortage. The second case requires five Progress Missions with a 100 L (218 lb) surplus. (Both cases assume 100 percent condensate collection in the USOS.)

Several options are available to address the water imbalance and the water shortage of the RS:

- Venting to space excess water on the USOS.
- Don't collect condensate on the USOS. This will not give the *ISS* a robust system, whereas at AC it is good to have this capability.
- Collect the condensate in a portable tank for transfer to the RS.
- Provide a temporary or permanent pipe to the RS.
- Transfer water from the space shuttle fuel cells which produce a net of about 60 L (132 lb) of potable water per day.

To make up for hygiene water losses, the RS has a tank that has a capacity of approximately 12 L (26 lb) which is part of the hygiene loop and is filled via a portable tank from any point. The water could come from the space shuttle AL, from the potable water processor, or from the Progress.

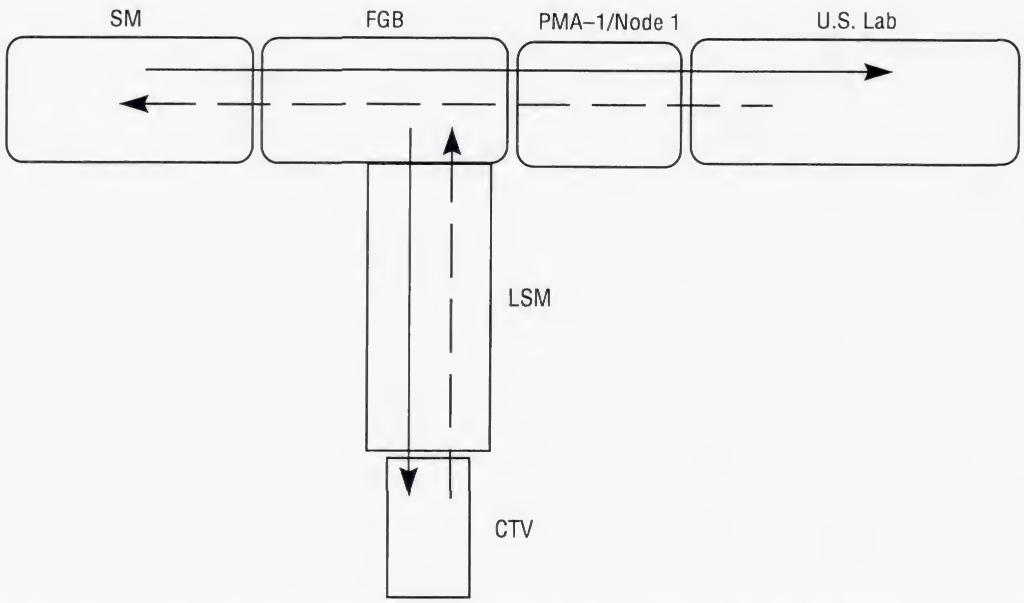


FIGURE 20.—*ISS* cooling and humidity removal loads configuration after the Russian LSM is installed.

Biocide Compatibility

The United States uses iodine for a biocide in the water supply, whereas the Russians use silver. If the different waters are mixed, intentionally or inadvertently, the iodine and silver can combine to form silver iodide, which precipitates as a solid, and can clog lines and diminish the biocide capabilities.

4.3 Responsibilities

Responsibilities are listed below:

- The Progress provides 170 kg (375 lb) of N_2 and O_2, each, at a pressure of 20.9 MPa (3027 psia, 206 atmospheres).
- The space shuttle provides fuel-cell water to the RS to produce metabolic O_2 for up to six crew members and O_2 for structural leakage for as long as the RS has to produce all of the O_2 for metabolic usage and structural leakage. The preliminary recommendation from the Russians is up to 150 kg/yr (330 lb/yr) (TBD).
- The space shuttle (or any other U.S. cargo spacecraft) supplies additional gases required for the USOS.
- The USOS provides for the release of excess pressure from the *ISS* after opening the hatch between segments.
- The USOS and RS maintain trace contaminants and particulates at the agreed levels.
- The space shuttle, after docking with the *ISS*, provides maintenance of the total pressure in the *ISS*.
- The USOS provides for denitrogenation for EVA's.

5.0 Safety, Reliability, and Quality Assurance

Due to the necessity for the ECLS systems to function properly, the design and manufacturing of the components must be of high quality. In addition to meeting the performance requirements with regard to the primary function, there are other aspects to the definition of quality: meeting requirements with regard to durability, maintainability, and repairability; safety; failure responses; and human factors considerations. These other aspects are discussed in this section. The "NASA/RSA Joint Specifications/Standards Document" further describes the specifications and standards.

5.1 System Durability and Maintainability

The design life for the *ISS* is 10 yr of operation after it is completely assembled. This means that the Russian systems are required to operate for 15 yr, since they will become operational about 5 yr prior to AC. To ensure that the entire system will be operational for such a long time, the subsystems and component parts are being designed to be highly reliable, maintainable when failures occur, and replaceable when necessary or when an improved technique is developed.

5.2 Human Factors and Other Requirements

Human factors considerations relate to those aspects with which the crew directly interacts. This includes allowable touch temperatures, surface roughness, equipment labeling, knobs, fasteners, and warning indicators such as fire signals. Allowable touch temperatures for continuous contact range between 5 and 40 °C (41 and 104 °F), and up to 45 °C (113 °F) for momentary contact. Surfaces at temperatures outside that range that are subject to contact must have warning labels, safety guards, or both. Exposed surfaces must be smooth and free of burrs. Equipment labeling must be in accordance with the "NASA/RSA Joint Specifications/Standards Document" for the *ISS*.

5.3 Safety Features

Safety features relate to structural, mechanical, electrical, chemical, and other aspects of ECLS equipment. Structurally, the equipment must withstand induced loads without damage under normal and expected conditions. In the event of a failure, the structure must not fail catastrophically (i.e., deformation must occur before fracture). Mechanically, the equipment must not damage other equipment if failure occurs. Electrically, the equipment must incorporate safety features such as interlocks whereby all electrical potentials in excess of 200 V are removed when equipment access doors are opened. Potential chemical hazards must be sealed sufficiently to preclude leakage. Any penetrations of the pressure shell must have two barriers to the space vacuum.

Regarding fire protection, the following capabilities are provided:

- Manual activation of a fire alarm within 1 min of detection of a fire event by the crew.
- Isolation of a fire must not cause loss of functionality that may create a catastrophic hazard.
- The application of a fire suppressant at each enclosed location containing a potential fire source must be accommodated.
- The fire suppressant must be compatible with the ECLS equipment, must not exceed 1 hr SMAC levels in any isolated elements, must be noncorrosive, and the byproducts must be compatible with the contamination control capability.
- One PBA and one PFE must be located in elements ≤7.3 m (24 ft) in accessible interior length. Where the element exceeds 7.3 m (24 ft) in accessible interior length, a set of PBA's and PFE's must be located within 3.7 m (12 ft) of each end of the element. At least one PBA must be located within 1 m (3 ft) of each PFE.

5.3.1 Failure Tolerance

Failure tolerance refers to how many failures a system can withstand before it no longer meets the required functions. Most of the ECLS functions are single-failure tolerant, meaning that any single failure will not prevent that function from being performed. Some functions are zero-failure tolerant, meaning that if a single failure occurred the function may be prevented. A single failure of RS equipment is not to propagate across the RS/USOS interfaces defined in SSP 42121, and failure of USOS equipment is not to propagate to the RS.

Equipment located in pressurized volumes will be capable of tolerating the differential pressure of depressurization, repressurization, and the depressurized condition without resulting in a hazard or failure propagation. Equipment that must operate during depressurization or repressurization is designed to operate over the entire pressure range without producing hazards.

If a system is not maintainable, with one or two failures crew return to Earth may be necessary. If a system is maintainable—the hydraulic system, for example—with one failure it can still support the crew, but since it is maintainable it could sustain many failures.

5.3.2 Design for Safety

The ECLSS design is such that no combination of two failures, two operator errors, or one of each can result in a catastrophic hazard; and no single failure or single operator error can result in a critical hazard.

Where hazards are controlled by requirements that specify safety related properties and characteristics, the affected .equipment must be designed for minimum risk. This applies to mechanisms, structures, pressure vessels, pressurized lines and fittings, functional pyrotechnic devices, material compatibility, flammability, etc. Equipment is designed such that a single failure of an ORU in a functional path will not induce any other failures external to the failed ORU.

5.4 Failure Response Procedures

Russian failure response procedures have been developed through experience with the *Salyut* and *Mir* stations. One example is the ventilation system. In the event that a component, such as a fan, of the ventilation system fails, the crew and ground controllers are alerted by a computer. The crew then replaces the fan to recover operation of the ventilation system. Similarly, if the humidity removal unit fails, the crew and Ground Control are alerted and activate a backup unit to recover.

Potential failures to the USOS ECLSS are evaluated and documented in Failure Modes and Effects Analyses (FMEA). Failures must be detectable to the ORU level. An ORU consists of several components attached together and treated as a single part. When an ORU fails the device containing that ORU is switched off and, if necessary, a backup device is switched on. The failed ORU is then removed and replaced with a spare ORU. The crew response depends on the type of failure. In the event of a fire, rapid depressurization, or hazardous atmospheric condition, the procedure is for the crew to don PBA's and then activate the caution and warning system by pressing the appropriate button on the nearest Caution and Warning (C&W) panel (shown in Chapter II: The USOS ECLSS, fig. 114). Other types of failures would have different response procedures.

5.5 Verification

Verifying that the required capabilities are provided by the completed system requires ensuring that the components that make up the system perform their required functions. Verification refers to tests or evaluations performed to ensure that equipment will function as designed when exposed to the flight environment. The verification methods that Russian, U.S., and international partners engineers use are similar, but have some differences. These methods are discussed in section 5.5.1.

Testing may be performed at different levels, such as component, assembly, or system. Also, testing may be performed at different phases of design, such as development, qualification, or acceptance. These terms are defined in sections 5.5.2 and 5.5.3.

Since the *ISS* will be operational for many years, it would be possible to perform some verification on orbit. This is undesirable for numerous reasons and it has been agreed to complete verification on the ground so that no on-orbit verification is needed. An example of a verification matrix showing the methods used to verify some of the life support capabilities is shown in table 11. A detailed verification plan specifies the objectives for verifying each capability. For more information see "Environmental Control and Life Support (ECLS) Architecture Description Document, Volume 3, ECLS Integration and Planning, Book 1, Verification Plan," Revision A, D684–10508–3–1, Boeing, 31 May 1996.

TABLE 11.—*An example verification matrix.*

Capability	Analysis	Inspection	Test
Control Atmospheric Pressure	√		√
Condition Atmosphere	√		√
Respond to Emergency Conditions	√		√
Control Internal CO_2 and Contaminants	√	√	√
Provide Water	√	√	√

Note: From presentation by Mo Saiidi, ECLS Working Group meeting, 3 to 5 June 1996, JSC.

5.5.1 Verification Methods

Verification of the *ISS* equipment by Russian engineers includes one or more of the following methods:

- In-flight testing
- Engineering analysis
- Modeling (with a low-fidelity mockup)
- Verification on the basis of previous test results or standard use, including previous flight test results
- Certification for use from previous applications (technical applicability and legal permission from the manufacturer)
- In-plant quality control
- Acceptance testing (testing upon delivery from manufacturer or subcontractor)
- Integrated test facility and launch site testing.

High-fidelity mockups are used for verification, developing procedures, training, and troubleshooting.

Verification of the *ISS* equipment by U.S. engineers includes one or more of the following methods:

- Test (T)—Environmental tests and functional tests
- Assessment by one or more of the following methods:
  - Analysis (A)—Analytical simulation by modeling, computer simulation, or other method including analysis of schematics, previous test results, or design documentation.
  - Demonstration (D)—Physical demonstration of compliance with requirements.
  - Similarity (S)—Comparison with a similar item that was previously qualified to equivalent or more stringent criteria.
  - Inspection (I)—Visual examination to verify construction features, workmanship, and physical condition.
  - Review of Records (R)—Review of reports to ensure that procedures were performed as required, that equipment performs properly, and that any problems identified during development have been corrected.

This classification of verification methods is sometimes shortened to Analysis, Inspection, Test, and Demonstration.

Verification of the *ISS* equipment by European engineers includes one or more of the following methods:

- Analysis/Similarity
- Inspection
- Test
- Review of Design (ROD)
- Demonstration (D).

5.5.2 Verification Levels

During the process of designing and developing a hardware item, each part must be designed for its particular function. Prior to assembling, parts are formally or informally tested to ensure that they will perform properly. This process is repeated at increasing levels of complexity as assembly progresses. Generally, verification at the system level and above involves reviewing the results of tests, inspecting of equipment or records, analyzing of results, or performing additional tests that are intended to ensure that a flight system meets its design and performance requirements and specifications. These levels of complexity may be defined as follows:

- Part—An indivisible item, such as a bolt or sensor.
- Component—A functional unit made up of parts, such as a pump or blower.
- Assembly—A group of related components performing a specific function, such as CO_2 removal or water processing, sometimes referred to as a subassembly.

- Subsystem—A group of related assemblies performing interconnected functions, such as atmospheric revitalization or water recovery and management. A subsystem may be packaged in a single rack.

- System—A hardware/software grouping that performs related functions across or within elements, such as ECLS, power distribution, or data management.

- Element—A major unit of a complex, such as a habitat module or power supply.

- Segment (for the *ISS*)—A group of elements that are the responsibility of the same country or consortium.

- Complex—An entire vehicle or habitat, such as the *ISS*.

For this document these definitions are used, although there are exceptions. The Europeans also use similar terminology. ORU's may be components or assemblies.

For the USOS, limited functional testing to ensure proper hardware operation is done at the rack level. There is no requirement to verify the integrated ECLS system, although testing of the Lab includes the integrated ECLS system.

5.5.3 Verification Phases

Formal testing generally occurs at specific phases in the process of designing and fabricating equipment. The U.S. and European practice is to perform the following tests:

- Development testing—Performed on early versions of the equipment that perform the desired function, but which may look different from the flight versions and be built to less exacting standards.

- Qualification testing—Performed on hardware identical to the flight hardware to determine whether the hardware can perform its required functions under the worst-case environments and stresses anticipated.

- Acceptance testing—Performed under normal operating conditions to check out the actual flight hardware and to ensure that it performs properly.

In addition to testing during the early development, qualification, and acceptance phases, verification typically also includes integrated system testing during prelaunch checkout, during flight operations, and post-flight.

5.5.4 Verification of ECLS Functions

The final verification of flight equipment is performed by the methods listed in the tables below. Prior to reaching this phase, the hardware will have been tested and analyzed numerous times at several phases of development. The verification methods used for each function and element of the RS are shown in table 12. The verification methods used for each function and element of the USOS are shown in table 13. The verification methods used for each function and element of the APM, JEM, and MPLM are shown in table 14. Verification methods have not been specified (as of April 1996) for some ECLS functions.

Table 12.—*Verification methods for RS ECLS functions.*

ECLS Function	FGB	SM	LSM	Cargo	RM
ACS					
Control Total Pressure					
Monitor Total Pressure	T, A	T, A		Flight	
Introduce N_2				Flight	
Control ppO_2					
Monitor ppO_2	T, A	T, A		Flight	
Introduce O_2		A		Flight	
Relieve Overpressure				Flight	
Equalize Pressure	A	A		Flight	
Respond to Rapid Decompression	–	A ,I			
Respond to Hazardous Atmosphere	I, A	A			
THC					
Control Atmospheric Temperature					
Monitor Atmospheric Temperature	T, A	T, A			
Remove Atmospheric Heat	T, A	T, A, S			
Control Atmospheric Moisture					
Monitor Humidity	T, A	T, A			
Remove Excess Moisture	–	T, A			
Dispose of Removed Moisture	–	A, I			
Circulate Atmosphere					
Intramodule	T, A	T, A			
Intermodule	T, A	T, A			
AR					
Control $ppCO_2$					
Monitor $ppCO_2$	T, A				
Remove CO_2	–	A		–	
Dispose of CO_2	–	I, R		–	
Control Gaseous Contaminants					
Remove Gaseous Contaminants	–	A			
Dispose of Gaseous Contaminants	–	I, R			
Control Airborne Particulate Contaminants	A	A			
Control Airborne Microorganisms	–	A			
FDS					
Respond to Fire					
Detect Fire	TBD	TBD			
Isolate Fire	TBD	TBD			
Extinguish Fire	TBD	TBD			
Recover From Fire	TBD	TBD			
WM					
Accommodate Crew Hygiene and Wastes	–	I, A, D		–	
WRM					
Provide Water for Crew Use					
Monitor Water Quality	–	A, T, I		–	
Supply Potable Water	–	A		–	
Supply Water for Hygiene Use	–	A		–	
Process Wastewater	–	TBD		–	

– indicates a function is not provided.

Table 13.—*Verification methods for USOS ECLS functions.*

ECLS Function	Lab	Hab	AL	Centrifuge	Node
ACS					
Control Total Pressure					
Monitor Total Pressure					
Introduce N_2				–	–
Control ppO_2					
Monitor ppO_2					
Introduce O_2				–	–
Relieve Overpressure					
Equalize Pressure					
Respond to Rapid Decompression					
Detect Rapid Decompression	A, T	A, T	A, T	A, T	A, T
Recover from Rapid Decompression	A, T, I	A, T, I	A, T, I	A, T, I	A, T, I
Respond to Hazardous Atmosphere					
Remove Hazardous Atmosphere	A, T	A, T	A, T	A, T	A, T
Recover From Hazardous Atmosphere	A, T, I	A, T, I	A, T, I	A, T, I	A, T, I
THC					
Control Atmospheric Temperature					
Monitor Atmospheric Temperature	A	A	A	A	A
Remove Atmospheric Heat	A	A	A	A	A
Control Atmospheric Moisture					
Monitor Humidity	A	A	A	A	A
Remove Excess Moisture	A	A	A	A	A
Dispose of Removed Moisture	A	A	A	A	A
Circulate Atmosphere					
Intramodule	A, T	A, T	A, T	A, T	A, T
Intermodule	A, T	A, T	A, T	A, T	A, T
AR					
Control CO_2					
Monitor CO_2					
Remove CO_2				–	–
Dispose of CO_2				–	–
Control Gaseous Contaminants					
Remove Gaseous Contaminants					–
Dispose of Gaseous Contaminants					–
Control Airborne Particulate Contaminants					
Control Airborne Microorganisms					
FDS					
Respond to Fire					
Detect Fire	A, T	A, T	A, T	A, T	A, T
Isolate Fire	A, T	A, T	A, T	A, T	A, T
Extinguish Fire	A, T, I, D	A, T, I, D	A, T, I, D	A, T, I, D	A, T, I, D
Recover From Fire	A, T, I	A, T, I	A, T, I	A, T, I	A, T, I
WM					
Accommodate Crew Hygiene and Wastes	–			–	–
WRM					
Provide Water for Crew Use					
Monitor Water Quality	N/A	A	N/A	N/A	N/A
Supply Potable Water		AI			
Supply Water for Hygiene Use		A			
Process Wastewater	N/A	A	N/A	N/A	N/A

– indicates a function is not provided.

Table 14.—*Verification methods for APM, JEM, and MPLM ECLS functions.*

ECLS Function	APM	JEM	MPLM
ACS			
Control Total Pressure			
Monitor Total Pressure	–		–
Introduce N_2			
Control ppO_2			
Monitor ppO_2	–	–	–
Introduce O_2			
Relieve Overpressure			
Equalize Pressure			
Detect Rapid Decompression	A,T	A,T	A,T
Respond to Hazardous Atmosphere			
Remove Hazardous Atmosphere			
Recover From Hazardous Atmosphere	I	I	I
THC			
Control Atmospheric Temperature			
Monitor Atmospheric Temperature			
Remove Atmospheric Heat			
Control Atmosphere Moisture			
Monitor Humidity			
Remove Excess Moisture			
Dispose of Removed Moisture			
Circulate Atmosphere			
Intramodule			
Intermodule			
AR			
Control $ppCO_2$			
Monitor $ppCO_2$			
Remove CO_2	–	–	–
Dispose of CO_2	–	–	–
Control Gaseous Contaminants			
Remove Gaseous Contaminants			–
Dispose of Gaseous Contaminants			–
Control Airborne Particulate Contaminants			–
Control Airborne Microorganisms			–
FDS			
Respond to Fire			
Detect Fire	A, T	A, T	A, T
Isolate Fire	A,T,D	A,T,D	A,T,D
Extinguish Fire	A, T, I, D	A, T, I, D	A, T, I, D
Recover From Fire	I	I	I
WM			
Accommodate Crew Hygiene and Wastes	–	–	–
WRM			
Provide Water for Crew Use			
Monitor Water Quality	–	–	–
Supply Potable Water	–	–	–
Supply Water for Hygiene Use	–	–	–
Process Wastewater	–	–	–

– indicates a function is not provided.

5.6 Failure Detection, Isolation, and Recovery

During periods of maintenance and non-nominal activity, the RS provides for manual control of automatic FDIR control processes. The ability is provided to detect and isolate off-nominal conditions or performance that may manifest a catastrophic or critical hazard without removal of equipment from its operating location or the use of ancillary test equipment. A catastrophic hazard is any hazard that may cause a disabling or fatal personnel injury, or cause the loss of, or render unusable, the space shuttle, Soyuz, or *ISS*. A critical hazard is any hazard that may cause a nondisabling personnel injury or illness, or loss of a major *ISS* element, on-orbit life sustaining function or emergency system, or involves damage to the space shuttle or Soyuz.

See table 15 for a listing of automatic FDIR ECLS capabilities.

TABLE 15.—*ECLS capabilities requiring automatic fault detection, isolation, and recovery (FDIR).*

ECLS Capability	Failure Detection	Isolation/ Recovery
Control Atmospheric Pressure		
Control Total Pressure	√	
Control Oxygen Partial Pressure	√	
Condition Atmosphere and Temperature Control		
Ventilation	√	
Hydraulic Loops	√	√
Moisture Collection	√	
Control Internal CO_2		
Control CO_2	√	
Control Gaseous Contaminants	√	
Provide Water for Crew Use	√	

Note: This table does not apply to the FGB

CHAPTER II: THE UNITED STATES ON-ORBIT SEGMENT AND ITS ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM

1.0 Introduction

The *ISS* USOS provides living and working space for up to six people in low-Earth orbit. A specialized laboratory module provides the capability for long-term scientific research, primarily in the areas of materials science, biology, and medicine. Earth observation and some astronomical research also may be performed.

1.1 The USOS Pressurized Elements

The USOS pressurized elements consist of:

- A laboratory module—the Lab
- A habitation module for three people, nominally—the Hab*
- Two nodes for connecting the modules—Nodes 1 and 2*
- An AL
- Three PMA's
- A cupola with windows for viewing external operations, including EVA's and use of the robotic arm
- A centrifuge module (planned, but not yet defined at the time of this writing).*

These elements are installed over a period of $4^1/_2$ yr, beginning in mid-1998. Russian participation allows Lab operations to begin after Flight 6A, in mid-1999. (The Russian SM provides some life support functions to the U.S. modules.) With the installation of the Hab in 2002, large-scale operations begin. The assembly sequence relating to ECLSS and the configuration at Assembly Complete (AC) is shown in chapter I of this report. See "Chapter I: Overview" for a general description of the USOS modules and their ECLS capabilities.

During the assembly process some modules, or components such as PMA's, are initially placed in temporary locations. Early in the assembly sequence the MPLM is attached to Node 1 and later to Node 2. Module repositioning may affect the ECLSS operation. These impacts, in general, are described in this report. (The impacts are described in more detail in "Stage Unique Requirements Reports" for each flight (D684–10199–flight number) and "Stage Assessment Reports" for each flight (D684–10239–flight number).)

1.2 The USOS ECLSS Functions

The ECLS functions performed in the USOS are identified in figure 21, using the standard categories employed by U.S. ECLSS designers.

* As noted in Chapter 1, due to recent program changes Node 2 and Node 3 (in place of the U.S. Hab) will be built by Italy and the centrifuge by Japan.

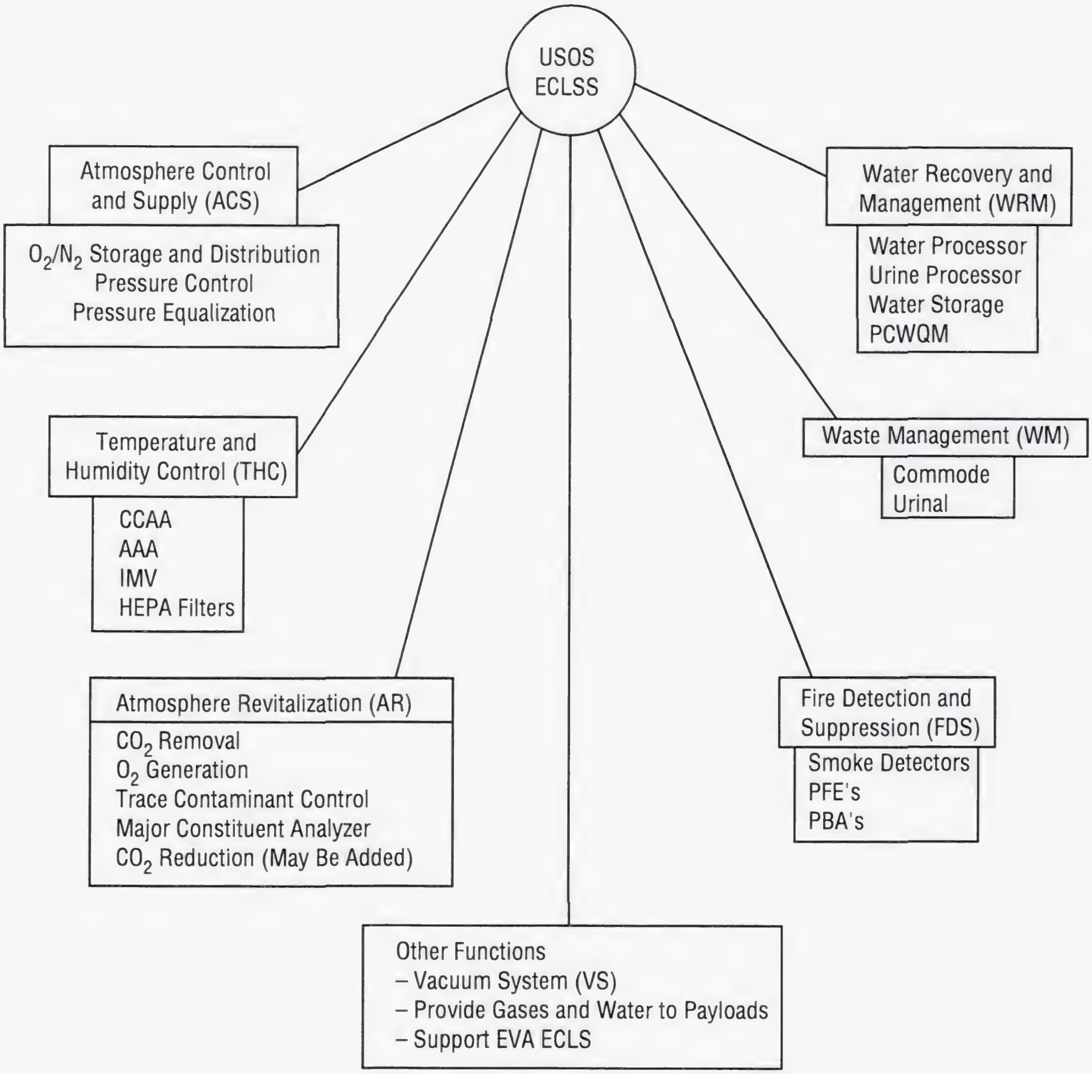


FIGURE 21.—USOS ECLSS functions.

2.0 Description of the USOS ECLSS

The USOS ECLS capabilities are listed in table 16 and the modules where they are performed are identified. These capabilities are described in section 2.1. The ECLS functions that are available at Flight 6A and Flight 19A are listed in table 17. Some of these functions are available before Flight 6A and Flight 19A. The monitoring and control consoles are described in section 2.2. Interconnections between the ECLS systems in different modules are discussed in section 2.3. Expendable components that must be resupplied are discussed in section 2.4.

Table 16.—*USOS ECLS capabilities and locations.*

Capability	Lab	Hab	Node 1	Node 2	AL	PMA	Centrifuge
ACS							
• Control Total Atmospheric Pressure							
– Monitor Total Atmospheric Pressure (3)	√	√	√	√	√	X	TBD
– Introduce Nitrogen	√	√	X	X	√	X	TBD
• Control Oxygen Partial Pressure							
– Monitor Oxygen Partial Pressure	√	√	√ (3)	√ (3)	√ (3)	X	TBD
– Introduce Oxygen (6)	√	√	X	X	√	X	TBD
• Relieve Overpressure	√	√	X	X	√	X	TBD
• Equalize Pressure	√	√	√	√	√	√ (2)	TBD
• Respond to Rapid Decompression							
– Detect Rapid Decompression	√	√	√	X	X	X	TBD
– Recover From Rapid Decompression	√	√	√	X	X	√	TBD
• Respond to Hazardous Atmosphere							
– Detect Hazardous Atmosphere (5)	√	√	X	X	√	X	TBD
– Remove Hazardous Atmosphere	√	√	√	√	√	X	TBD
– Recover From Hazardous Atmosphere	√	√	√	√	√	X	TBD
THC							
• Control Atmospheric Temperature							
– Monitor Atmospheric Temperature	√	√	X	√	√	X	TBD
– Remove Atmospheric Heat	√	√	X	√	√	X	TBD
• Control Atmospheric Moisture							
– Monitor Humidity	X	X	X	X	X	X	TBD
– Remove Atmospheric Moisture	√	√	X	√	√	X	TBD
– Dispose of Removed Moisture	√	√	X	√	√	X	TBD
• Control Airborne Particulate Contaminants							
– Remove Airborne Particulate Contaminants	√	√	√	√	√	X	TBD
– Dispose of Airborne Particulate Contaminants	√	√	√	√	√	X	TBD
• Control Airborne Microbial Growth							
– Remove Airborne Microorganisms	√	√	√	√	√	X	TBD
– Dispose of Airborne Microorganisms	√	√	√	√	√	X	TBD
• Circulate Atmosphere: Intramodule	√	√	√	√	√	X	TBD
• Circulate Atmosphere: Intermodule	√	√	√	√	√	X	TBD
AR							
• Control CO_2							
– Monitor CO_2 (3)	√	√	√ (3)	√ (3)	√ (3)	X	TBD
– Remove CO_2	√	√	X	X	√ (4)	X	TBD
– Dispose of CO_2	√	√	X	X	√ (4)	X	TBD
• Control Gaseous Contaminants							
– Monitor Gaseous Contaminants (5)	√	√	X	X	X	X	TBD
– Remove Gaseous Contaminants	√	√	X	X	X	X	TBD
– Dispose of Gaseous Contaminants	√	√	X	X	X	X	TBD
FDS							
• Respond to Fire							
– Detect a Fire Event	√	√	√	√	√	X	TBD
– Isolate Fire Control Zone	√	√	X	√	√	X	TBD
– Extinguish Fire	√	√	√	√	√	X	TBD
– Recover From a Fire	√	√	X	X	√	X	TBD
WM							
• Accommodate Crew Hygiene and Wastes	X	√	X	X	X	X	TBD

TABLE 16.—*USOS ECLS capabilities and locations (continued).*

Capability	Lab	Hab	Node 1	Node 2	AL	PMA	Centrifuge
WRM (6)							
• Provide Water for Crew Use							
– Monitor Water Quality	X	√	X	X	X	X	TBD
– Supply Potable Water	X	√	X	X	√	X	TBD
– Supply Hygiene Water	X	√	X	X	X	X	TBD
– Process Wastewater	X	√	X	X	X	X	TBD
• Supply Water for Payloads	√	√	X	X	X	X	TBD
VS							
• Supply Vacuum Services to User Payloads							
– Provide Waste Gas Exhaust	√	X	X	X	X	X	TBD
– Provide Vacuum Resource	√	X	X	X	X	X	TBD
EVA Support							
• Support Denitrogenation							
– Support In-Suit Prebreathe	X	X	X	X	√	X	TBD
– Support Campout Prebreathe	X	X	X	X	√	X	TBD
• Support Service and Checkout							
– Provide Water	X	√	X	X	√	X	TBD
– Provide Oxygen	X	X	X	X	√	X	TBD
– Provide In-Suit Purge	X	X	X	X	√	X	TBD
• Support Station Egress							
– Evacuate Airlock	X	X	X	X	√	X	TBD
• Support Station Ingress							
– Accept Wastewater	X	√	X	X	√ (1)	X	TBD
Other							
Distribute Gases to User Payloads	√	X	X	X	X	X	TBD

Notes:
√ indicates that a capability is provided.
X indicates that a capability is not provided.
TBD indicates that it is unknown or not yet determined whether a capability will be provided.

(1) Wastewater is delivered to Node 1 through the wastewater bus and then is delivered to the Hab for processing after Hab outfitting. Prior to Hab outfitting, the wastewater is stored in the condensate tank in the Lab.
(2) PMA–1 does not have a hatch and, therefore, no pressure equalization capability.
(3) Atmospheric composition is monitored by the MCA, which is part of the AR subsystem in the Lab and Hab. The MCA monitors the partial pressures of O_2, N_2, H_2, CO_2, and CH_4 via the SDS.
(4) For campout only.
(5) Provided by CHeCS, which is in the Lab initially. After the Hab is installed, CHeCS is moved to the Hab. CHeCS can be installed in any module.
(6) Water for electrolysis to provide O_2 is supplied by the WRM subsystem from the water processor.

2.1 USOS ECLSS System Design and Operation

The USOS ECLS system, as shown in figure 22, consists of several subsystems that work together to provide the necessary ECLS functions. In addition, the USOS ECLSS includes vacuum services for payloads and support for EVA's. Some of the ECLS functions are performed in a "stand-alone" manner, without requiring the operation of another subsystem (e.g., fire suppression and vacuum services), while others involve interconnections with other ECLS functions (e.g., humidity condensate water is processed for reuse).

The ECLS functional categories and the capabilities included in each category are identified below. The functional categories are based on hardware grouping, while the capabilities are based on tasks to be performed as described in the USOS Specification. This results in some overlap where a particular piece of hardware provides multiple capabilities.

Atmosphere Control and Supply (ACS) includes monitoring the atmospheric pressure and the ppO_2 (performed by the AR subsystem); storing and adding N_2 and O_2 to the atmosphere; relieving overpressure; equalizing pressure between adjacent modules; detecting

Table 17.—*The major USOS ECLS hardware items and their locations.*

Function	Capability or Device	Flight 6A	Flight 19A
Atmosphere Control and Supply	Pressure Control Assembly	Lab	AL, Hab, Lab
	O_2/N_2 Storage Tanks	X	AL
	Pressure Equalization Valves	All Hatches Between Pressurized Modules	
Temperature and Humidity Control	Common Cabin Air Assembly	Lab	Lab, Hab, AL, Node 2
	Avionics Air Assembly	Lab	Lab, Hab
	HEPA Filters (in all except the PMA's)	Lab, Node 1	Lab, Hab, Nodes 1 and 2, AL
	Intermodule Ventilation	Node 1, Lab	Nodes 1 and 2, Lab, Hab
	Ventilation only for Node 1	Node 1	Node 1
Atmosphere Revitalization	CO_2 Removal (by CDRA in Hab and Lab, LiOH in AL)	Lab	Lab, Hab, AL
	Trace Contaminant Control	Lab	Lab, Hab
	Major Constituent Analyzer	Lab	Lab, Hab
	Oxygen Generation/Supply	X	Hab
	CO_2 Reduction (Interface Connections Only)	X	X
Fire Detection and Suppression	Fire Detection (Smoke Detectors in all Modules Except PMA)	Lab, Node 1	Lab, Hab, Nodes 1 and 2, AL
	Fire Suppression (PFE's in all Modules Except PMA)	Lab Node 1	Lab, Hab, Nodes 1 and 2, AL
Waste Management	Commode/Urinal	X	Hab
Water Recovery and Management	Water Processing	X	Hab
	Fuel-Cell Water Storage	X	Lab
	Condensate Storage	Lab	Lab Backup
	Urine Processing	X	Hab
	Water Quality Monitor	X	Hab
	Water Vents	Lab	Lab
Vacuum Services	Vacuum Exhaust, Vacuum Resource	Lab	Lab

Note: X indicates that the capability is not present.

and recovering from rapid decompression; and detecting, removing, and recovering from hazardous atmosphere. O_2 is provided from stored gaseous O_2 and by electrolysis of water.

Temperature and Humidity Control (THC) includes removing moisture and heat from the atmosphere by CHX's that remove moisture and heat simultaneously. Circulation of the atmosphere within each module, ventilation of atmosphere between modules, and removal and disposal of airborne microbial and particulate contaminants are also provided by the THC subsystem.

Atmosphere Revitalization (AR) includes CO_2 monitoring, removal, and disposal; and atmospheric trace contaminant removal and disposal. The capability to later add CO_2 reduction may also be provided. Monitoring of the major atmospheric constituents is considered an AR function, but the capability requirements are related to other ECLS functions as well. (Trace contaminant monitoring is performed by the CHeCS, which is part of "crew systems" rather than the ECLS.)

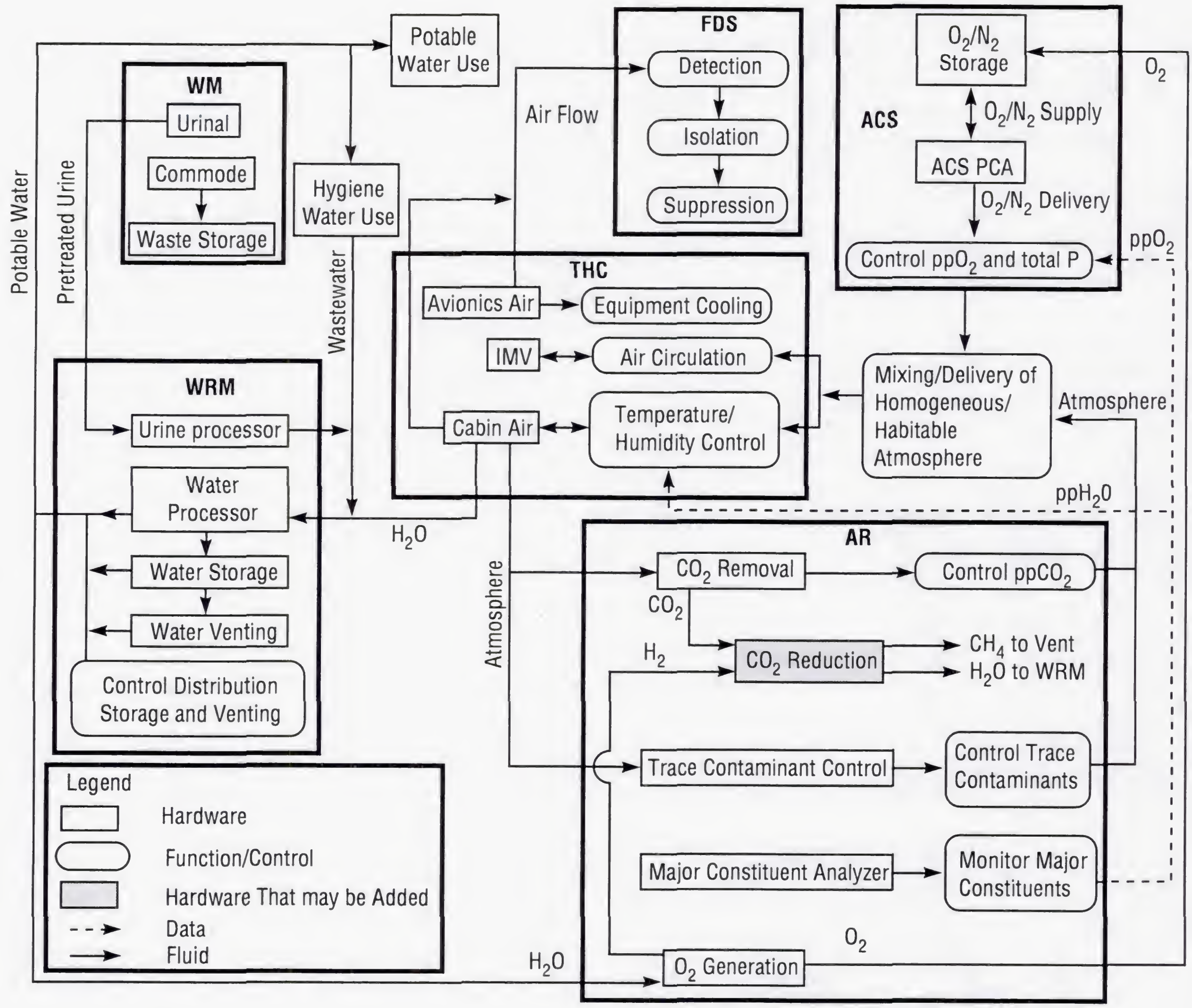


Figure 22.—USOS ECLS functional integration (Revision of Figure 2 from D683-40013-1).

Fire Detection and Suppression (FDS) includes detection of smoke (some combustion gases are detected by the CHeCS), isolation of fires, the means to extinguish fires, and the means to recover from fires.

Waste Management (WM) includes the means to process or stabilize metabolic wastes. The WM subsystem includes a commode and urinal.

Water Recovery and Management (WRM) includes monitoring the water quality, supplying potable water, supplying hygiene water, processing wastewater (including water recovered from urine) and humidity condensate, and supplying water for payloads. The WRM also vents excess wastewater and includes storage of condensate, wastewater, and fuel-cell water in the Lab.

Vacuum Services (VS) include a waste gas exhaust subsystem to vent waste gases to space and a vacuum resource subsystem to provide a vacuum source to experiment payloads.

Extravehicular Activity (EVA) Support includes preparing astronauts for EVA's by "campout" prebreathe and in-suit prebreathe; supporting EVA's by supplying water, O_2, and suit purge capability; evacuating the AL; and accepting wastewater produced during an EVA.

Other capabilities include providing gases (N_2) to user payloads.

2.2 ECLS Monitoring and Control

The ECLSS is operated from Portable Computer System (PCS) workstations that are used to command, control, and monitor the USOS systems. The PCS is a "laptop" computer, as shown in figure 23, which can be connected via interface ports at various locations. Operation is controlled by software that is specific for each system, subsystem, or assembly. In addition, a C&W panel (shown in fig. 114) provides warning of potentially hazardous conditions.

2.3 ECLS Interconnections Between the Elements

The *ISS* modules are interconnected in numerous ways. ECLS interconnections include atmospheric movement through hatchways and ducts which transfers moisture and thermal energy as well as O_2, CO_2, and trace contaminants; plumbed interconnections for water; and atmosphere sample collection lines. The ECLS fluid interconnections through PMA–2 and PMA–3 are shown in figure 24. The interconnections for the APM, JEM, and MPLM are shown in chapter III, figures 146, 147, and 148, respectively. The mass and energy flows are listed in table 18.

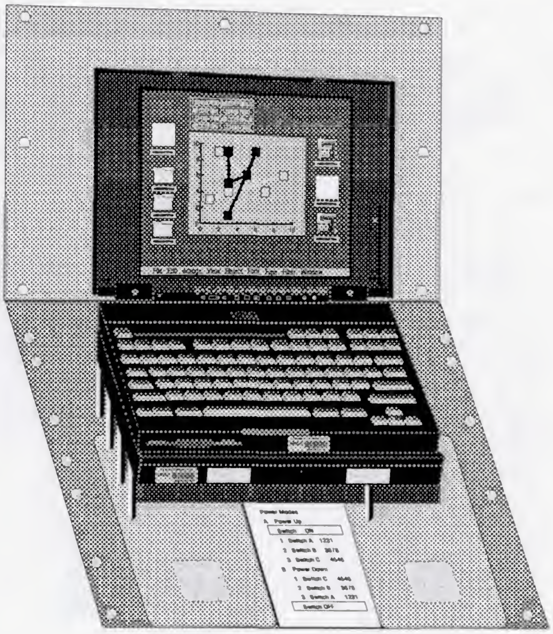


FIGURE 23.—USOS PCS "laptop" computer.

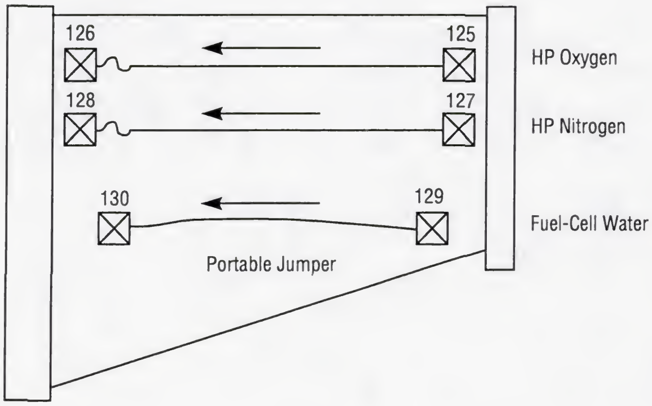


FIGURE 24.—ECLS interconnections through PMA–2 and PMA–3.

There are several types of connectors that are used, as listed in table 19. Two types are shown in figure 25. "Jumpers" are hoses or ducts that connect the fluid lines across the vestibules.

2.4 Logistics Resupply

As much as feasible, regenerable technologies are used for the ECLSS. Some expendable components are used, however, and these must be resupplied. The expendables include filters, trace contaminant sorbent beds, and other items. The expendable items and replaceable components are listed in table 20 for each ECLS function, with the period of replacement.

TABLE 18.—*ECLS mass and energy flows between modules.*

Parameter		Node 1/Hab	Lab/Node 1	Node 1/Cupola	Lab/Node 2
	Part I Document (SSP)	41140	41141	41142	41143
	Part II Document (SSP)	41140	41141	41142	41143
IMV Supply	Temperature—°C (°F)	18.3–29.5 (65–85)	7.2–29. 5 (45–85)	7.2–29.5 (45–85)	18.3–29.5 (65–85)
	Dewpoint—°C (°F)				
	Pressure—bar (psia)	0.9–1.03 (13.9–15.2)	0.9–1.03 (13.9–15.2)	0.9–1.03 (13.9–15.2)	0.9–1.03 (13.9–15.2)
	Press Loss—Pa (inch of H_2O)	N/A	N/A	37 (0.15)	72 (0.29)
	Min Flowrate—m^3/hr (cfm)	N/A	N/A	220 (130)	212 (125)
IMV Return	Temperature—°C (°F)	18.3–29.5 (65–85)	18–29.5 (65–85)	N/A	18.3–29.5 (65–85)
	Dewpoint—°C (°F)				
	Pressure—bar (psia)	0.9–1.03 (13.9–15.2)	0.9–1.03 (13.9–15.2)	N/A	0.9–1.03 (13.9–15.2)
	Min Flowrate—m^3/hr (cfm)	203 (120)	212 (125)	N/A	220 (130)
Nitrogen	Temperature—°C (°F)	15.6–45 (60 to 113)	15.6–45 (60 to 113)	N/A	15.6–45 (60 to 113)
	Pressure—bar (psia)	6.3–8.2 (93 to 120)	6.3–8.2 (93 to 120)	N/A	6.3–8.2 (93 to 120)
	Flowrate—kg/hr (lb/min)	0–0.09 (0–0.2)	0–0.09 (0–0.2)	N/A	0–0.09 (0–0.2)
	Max Design Press—bar (psia)	13.6 (200)	13.6 (200)	N/A	13.6 (200)
Oxygen	Temperature—°C (°F)	15.6–45 (60 to 113)	15.6–45 (60 to 113)	N/A	5.6–45 (60 to 113)
	Pressure—bar (psia)	6.3–8.2 (93 to 120)	6.3–8.2 (93 to 120)	N/A	6.1–8.2 (90 to 120)
	Flowrate—kg/hr (lb/min)	0–0.09 (0–0.2)	0–0.09 (0–0.2)	N/A	0–0.09 (0–0.2)
	Max Design Press—bar (psia)	13.6 (200)	13.6 (200)	N/A	13.6 (200)
Recharge Nitrogen	Temperature—°C (°F)	–3.9–45 (25 to 113)	–3.9–45 (25 to 113)	N/A	0–45 (25 to 113)
	Flowrate—kg/hr (lb/min)	0–1.4 (0–3)	0–1.4 (0–3)	N/A	0–1.4 (0–3)
	Max Design Press—bar (psia)	231 (3,400)	231 (3,400)	N/A	231 (3,400)
Recharge Oxygen	Temperature—°C (°F)	–3.9–45 (25 to 113)	–3.9–45 (25 to 113)	N/A	0–45 (25 to 113)
	Flowrate—kg/hr (lb/min)	0–7.3 (0–16)	0–7.3 (0–16)	N/A	0–7.3 (0–16)
	Max Design Press—bar (psia)	72 (1,050)	72 (1,050)	N/A	72 (1,050)
Wastewater Nominal Only	Temperature—°C (°F)	12.7–45 (55 to 113)	12.7–45 (55–113)	N/A	12.7–45 (55–113)
	Pressure—bar (psig)	0–0.6 (0–8)	0–0.6 (0–8)	N/A	0–0.6 (0–8)
	Max Design Press—bar (psig)	5.85 (85)	5.85 (85)	N/A	5.85 (85)
	Flowrate—kg/hr (lb/hr)	0–0.9 (0–2)	0–0.9 0–2)	N/A	0–0.9 (0–2)
Fuel-Cell Water	Temperature—°C (°F)	18.3–45 (65–113)	18.3–45 (65–113)	N/A	18.3–45 (65–113)
	Pressure—bar (psig)	0–1.4 (0–20)	0–1.4 (0–20)	N/A	0–1.4 (0–20)
	Flowrate—kg/hr (lb/min)	0–1.8 (0–4)	0–1.8 (0–4)	N/A	0–1.8 (0–4)
Atmosphere Sample Air	Temperature—°C (°F)	18.3–29.5 (65–85)	18.3–29.5 (65–85)	N/A	18.3–29.5 (65–85)
	Pressure—bar (psia)	0.9–1.03 (13.9–15.2)	0.9–1.03 (13.9–15.2)	N/A	0.9–1.03 (13.9–15.2)
	Flowrate—scc/min	100 to 400	100 to 400	N/A	100 to 400

TABLE 18.—*ECLS mass and energy flows between modules (continued).*

Parameter		Node1/AL	Node 2/Centrifuge	Node 2/APM	Node 2/JEM
	Part I Document (SSP)	41145	41147	41150	41151
	Part II Document (SSP)	41145	41147	42001	42000
IMV Supply	Temperature—°C (°F)	18.3–26.7 (65–80)	18.3–29.5 (65–85)	18.3–29.5 (65–85)	7.2–29. 5 (45–85)
	Dewpoint—°C (°F)				
	Pressure—bar (psia)	0.9–1.03 (13.9–15.2)	0.9–1.03 (13.9–15.2)	0.9–1.03 (13.9–15.2)	0.9–1.03 (13.9–15.2)
	Press Loss—Pa (inch of $H_2$0)	117 (0.48)	62 (0.25)	117 (0.71)	115 (0.46)
	Min Flowrate—m^3/hr (cfm)	195 (115)	220 (130)	220 (130)	237 (140)
IMV Return	Temperature—°C (°F)	18.3–29.5 (65–85)	18.3–29.5 (65–85)	18.3–29.5 (65–85)	18–29.5 (65–85)
	Dewpoint—°C (°F)				
	Pressure—bar (psia)	0.9–1.03 (13.9–15.2)	0.9–1.03 (13.9–15.2)	125 (0.5)	137 (0.55)
	Min Flowrate—m^3/hr (cfm)	N/A	204 (120)	237 (140)	237 (140)
Nitrogen	Temperature—°C (°F)	15.6–45 (60 –113)	15.6–45 (60 to 113)	15.6–45 (60 to 113)	15.6–45 (60 to 113)
	Pressure—bar (psia)	6.3–8.2 (93–120)	6.3–8.2 (93 to 120)	6.3–8.2 (93 to 120)	6.3–8.2 (93 to 120)
	Flowrate—kg/hr (lb/min)	0–0.09 (0–0.2)	0–0.09 (0–0.2)	0–0.09 (0–0.2)	0–0.09 (0–0.2)
	Max Design Press—bar (psia)	13.6 (200)	13.6 (200)	13.6 (200)	13.6 (200)
Oxygen	Temperature—°C (°F)	5.6–45 (60–113)	5.6–45 (60 to 113)	N/A	N/A
	Pressure—bar (psia)	6.5–8.2 (95–120)	6–8.2 (88–120)	N/A	N/A
	Flowrate—kg/hr (lb/min)	0–0.09 (0–0.2)	N/A	N/A	N/A
	Max Design Press—bar (psia)	13.6 (200)	N/A	N/A	N/A
Recharge Nitrogen	Temperature—°C (°F)	0–45 (25–113)	N/A	N/A	N/A
	Flowrate—kg/hr (lb/min)	0–1.4 (0–3)	N/A	N/A	N/A
	Max Design Press—bar (psia)	231 (3,400)	N/A	N/A	N/A
Recharge Oxygen	Temperature—°C (°F)	0–45 (25–113)	N/A	N/A	N/A
	Flowrate—kg/hr (lb/min)	0–7.3 (0–16)	N/A	N/A	N/A
	Max Design Press—bar (psia)	72 (1,050)	N/A	N/A	N/A
Wastewater Nominal Only	Temperature—°C (°F)	15.6–45 (60–113)	12.7–45 (55–113)	12.7–45 (55–113)	12.7–45 (55–113)
	Pressure—bar (psig)	0–0.6 (0–8)	0–0.6 (0–8)	0–0.6 (0–8)	0–0.6 (0–8)
	Max Design Press—bar (psig)	5.85 (85)	3.1 (45)	3.1 (45)	3.1 (45)
	Flowrate—kg/hr (lb/hr)	0–0.23 (0–0.5)	0–0.23 (0–0.5)	0–0.23 (0–0.5)	0–0.23 (0–0.5)
Fuel-Cell Water	Temperature—°C (°F)	N/A	18.3–45 (65–113)	N/A	N/A
	Pressure—bar (psig)	N/A	0–1.4 (0–20)	N/A	N/A
	Flowrate—kg/hr (lb/min)	N/A	0–1.8 (0–4)	N/A	N/A
Atmosphere Sample Air	Temperature—°C (°F)	18.3–29.5 (65–85)	18.3–29.5 (65–85)	18.3–29.5 (65–85)	117.2–45 (63 to 113)
	Pressure—bar (psia)	0.7–1.03 (10.2–15.2)	0.9–1.03 (13.9–15.2)	0.9–1.03 (13.9–15.2)	0.7–1.03 (11–15.2)
	Flowrate—scc/min	100 to 400	100 to 400	100 to 400	0 to 400

Table 18.—*ECLS mass and energy flows between modules (continued).*

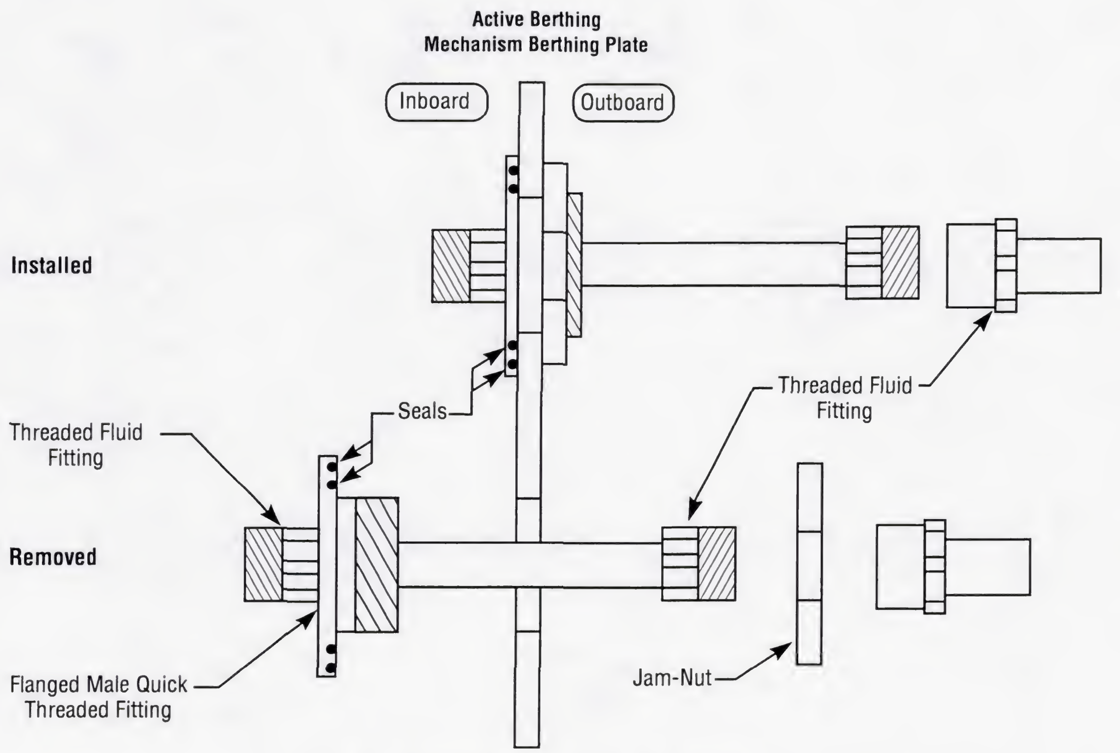
Parameter		ISPR	Node 2/MPLM	Node 2/P2:U/P2:H/P3:Node 1/P3	PMA–1/FGB
	Part I Document (SSP)	41152	42007	42097	42121
	Part II Document (SSP)	41002	42007	42097	42121
IMV Supply	Temperature—°C (°F)	N/A	7.2–29.5 (45–85)	18.3–29.5 (65–85)	18.3–28 (65–82.4)
	Dewpoint—°C (°F)				4.4–13.9 (40-57)
	Pressure—bar (psia)	N/A	0.9–1.03 (13.9–15.2)	0.9–1.03 (13.9–15.2)	0.9–1.03 (13.9–15.2)
	Press Loss—Pa (inch of H_2O)	N/A	229 (0.9)	N/A	1 (0.004)
	Min Flowrate—m^3/hr (cfm)	N/A	229 (135)	229–246 (135–145)	215–251 (127–148)
IMV Return	Temperature—°C (°F)	N/A	18.3–29.5 (65–85)	18.3–29.5 (65–85)	18.3–29.5 (65–85)
	Dewpoint—°C (°F)				
	Pressure—bar (psia)	N/A	174 (0.7)	N/A	N/A
	Min Flowrate—m^3/hr (cfm)	N/A	229 (135)	229–246 (135–145)	215–251 (127–148)
Nitrogen	Temperature—°C (°F)	N/A	N/A	N/A	N/A
	Pressure—bar (psia)	N/A	N/A	N/A	N/A
	Flowrate—kg/hr (lb/min)	N/A	N/A	N/A	N/A
	Max Design Press—bar (psia)	N/A	N/A	N/A	N/A
Oxygen	Temperature—°C (°F)	N/A	N/A	N/A	N/A
	Pressure—bar (psia)	N/A	N/A	N/A	N/A
	Flowrate—kg/hr (lb/min)	N/A	N/A	N/A	N/A
	Max Design Press—bar (psia)	N/A	N/A	N/A	N/A
Recharge Nitrogen	Temperature—°C (°F)	N/A	N/A	0–45 (25 to 113)	N/A
	Flowrate—kg/hr (lb/min)	N/A	N/A	0–1.4 (0–3)	N/A
	Max Design Press—bar (psia)	N/A	N/A	231 (3,400)	N/A
Recharge Oxygen	Temperature—°C (°F)	N/A	N/A	0–45 (25 to 113)	N/A
	Flowrate—kg/hr (lb/min)	N/A	N/A	0–7.3 (0–16)	N/A
	Max Design Press—bar (psia)	N/A	N/A	72 (1,050)	N/A
Wastewater Nominal Only	Temperature—°C (°F)	N/A	N/A	N/A	N/A
	Pressure—bar (psig)	N/A	N/A	N/A	N/A
	Max Design Press—bar (psig)	N/A	N/A	N/A	N/A
	Flowrate—kg/hr (lb/hr)	N/A	N/A	N/A	N/A
Fuel-Cell Water	Temperature—°C (°F)	N/A	N/A	18.3–45 (65–113)	N/A
	Pressure—bar (psig)	N/A	N/A	0–1.4 (0–20)	N/A
	Flowrate—kg/hr (lb/min)	N/A	N/A	0–1.8 (0–4)	N/A
Atmosphere Sample Air	Temperature—°C (°F)	N/A	18.3–29.5 (65–85)	N/A	N/A
	Pressure—bar (psia)	N/A	0.9–1.03 (13.9–15.2)	N/A	N/A
	Flowrate—scc/min	N/A	0 to 400	N/A	N/A

TABLE 18.—*ECLS mass and energy flows between modules (continued).*

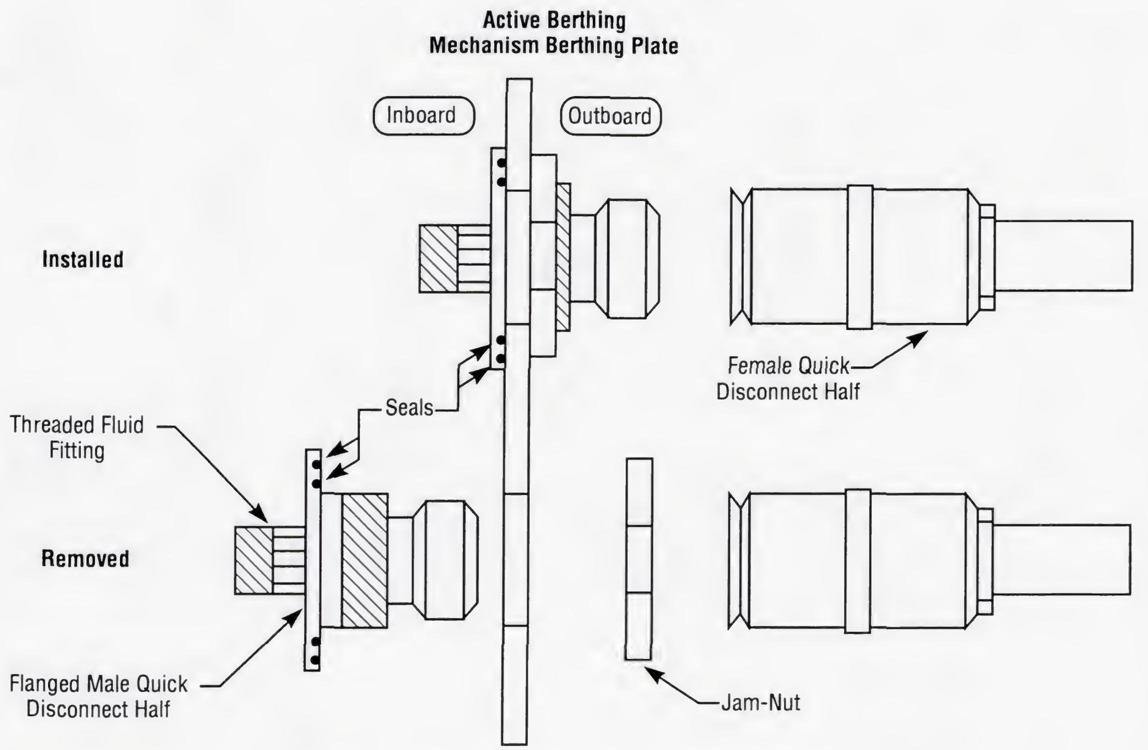
Parameter		Node 1/PMA1	ISSA/PBA	Shuttle to PMA
	Part I Document (SSP)	42122	50104	NSTS–21000–IDD
	Part II Document (SSP)	42122	N/A	N/A
IMV Supply	Temperature—°C (°F)	18.3–29.5 (65–85)	7N/A	12.8–29.4 (55–85)
	Dewpoint—°C (°F)			
	Pressure—bar (psia)	N/A	N/A	N/A
	Press Loss—Pa (inch of $H_2$0)	N/A	N/A	N/A
	Min Flowrate—m^3/hr (cfm)	229–246 (135–145)	N/A	64.8–99 (38–58)
IMV Return	Temperature—°C (°F)	18.3–29.5 (65–85)	N/A	18.3–29.5 (65–85)
	Dewpoint—°C (°F)			
	Pressure—bar (psia)	N/A	N/A	N/A
	Min Flowrate—m^3/hr (cfm)	229–246 9135–145)	N/A	64.8–99 (38–58)
Nitrogen	Temperature—°C (°F)	N/A	N/A	N/A
	Pressure—bar (psia)	N/A	N/A	N/A
	Flowrate—kg/hr (lb/min)	N/A	N/A	N/A
	Max Design Press—bar (psia)	N/A	N/A	N/A
Oxygen	Temperature—°C (°F)	N/A	15.6–45 (60 to 113)	N/A
	Pressure—bar (psia)	N/A	4.8–8.2 (70–120)	N/A
	Flowrate—kg/hr (lb/min)	N/A	0–0.09 (0–0.2)	N/A
	Max Design Press—bar (psia)	N/A	13.6 (200)	N/A
Recharge Nitrogen	Temperature—°C (°F)	N/A	N/A	–3.9–45 (25 to 113)
	Flowrate—kg/hr (lb/min)	N/A	N/A	0–1.4 (0–3)
	Max Design Press—bar (psia)	N/A	N/A	231 (3,400)
Recharge Oxygen	Temperature—°C (°F)	N/A	N/A	–3.9–45 (25 to 113)
	Flowrate—kg/hr (lb/min)	N/A	N/A	0–7.3 (0–16)
	Max Design Press—bar (psia)	N/A	N/A	72 (1,050)
Wastewater Nominal Only	Temperature—°C (°F)	N/A	N/A	N/A
	Pressure—bar (psig)	N/A	N/A	N/A
	Max Design Press—bar (psig)	N/A	N/A	N/A
	Flowrate—kg/hr (lb/hr)	N/A	N/A	N/A
Fuel-Cell Water	Temperature—°C (°F)	N/A	N/A	18.3–45 (65–113)
	Pressure—bar (psig)	N/A	N/A	0–1.4 (0–20)
	Flowrate—kg/hr (lb/min)	N/A	N/A	0–1.8 (0–4)
Atmosphere Sample Air	Temperature—°C (°F)	N/A	N/A	N/A
	Pressure—bar (psia)	N/A	N/A	N/A
	Flowrate—scc/min	N/A	N/A	N/A

TABLE 19.—*Vestibule fluid feedthroughs and jumpers.*

Interface Hardware	Description
Threaded Fluid Fitting Feedthrough	This feedthrough consists of a fitting that is threaded at both ends, with a flange having two O-ring seals. This fitting is inserted through a D-hole in the bulkhead and secured with a jam-nut. A vestibule jumper with a threaded fitting connects to this feed-through. This type of feedthrough is used for permanent module interfaces.
Self-Sealing Quick Disconnect (QD) Feedthrough	This feedthrough consists of a fitting that is threaded at one end and has a QD fitting at the other, with a flange having two O-ring seals. This fitting is inserted through a D-hole in the bulkhead and secured with a jam-nut. A vestibule jumper with a QD fitting connects to this feedthrough. This type of feedthrough is used for temporary module interfaces, such as between the MPLM and Node 2.
IMV Module Interfaces	IMV jumpers are hard, sound-attenuating ducts with half of a V-band coupling on each end.
Flex Hose Assembly	Flexible hoses are used for jumpers other than the IMV jumper. The flex hoses are Teflon™ with a braided Nomex™ cover. A threaded fitting or QD is attached at each end of a flex hose to make a jumper.
Sample Line Module Interfaces	Sample line jumpers have non-self-sealing QD's at each end, for permanent and temporary module interfaces.



(A): Threaded Fluid Fitting Feedthrough



(B): Self-Sealing Quick Disconnect Feedthrough

FIGURE 25.—USOS vestibule fluid connectors.

TABLE 20.—*USOS ECLS components.*

Assembly/ORU	Qty.	Qty. Spares	Mass, kg (lb)	Volume, L (ft3)	Avg. Power, W	Peak Power, W	Replacement Period	Crew Time, MMH/yr.	Ressupply mass, kg/yr (lb/yr)	Ressupply Vol., L/yr (ft3/yr)	Notes
Atmosphere Control and Supply (ACS)											
Cabin Pressure Sensor			0.30 (0.66)								Hamilton Standard
Vent/Relief Valve	3	2	5.4 (12)	14.1 (0.5)	0	<30		0	0	0	
Pressure Control Panel	3	0	11.2 (24.8)	34.0 (1.2)	18	116		0	0	0	
Manual Pressure Equalization Valve	24	1	1.2 (2.6)	1.4 (0.05)	0	0		0	0	0	
Positive Pressure Relief Valve	6	0	0.9 (2.0)	1.7 (0.06)	0	0		0	0	0	
Negative Pressure Relief Valve	9	0	1.0 (2.2)	3.1 (0.11)	0	0		0	0	0	
Nitrogen Interface Assembly	3	1	7.5 (16.6)	12.2 (0.43)	5.5 enabled	40		0	0	0	
Vacuum Access Jumper (5 ft.)	1	0	0.7 (1.6)	0.43 (0.02)	0	0		0	0	0	
Vacuum Access Jumper (35 ft.)	1	0	3.2 (7.0)	3.0 (0.1)	0	0		0	0	0	
02 Tank ORU	2	1	544 (1200) 109 (240) dry tank wt.; 91 (200) gas	4585 (162)	0	0	10 y service life ≥ 10 Launches)	EVA/EVR Combin-ation	544 (1200); 100 kg/yr (200 lb/yr)	4585 (162)	externally mounted on the AL
N2 Tank ORU	2	1	544 (1200); 109 (240) dry tank wt.; 91 (200) gas	4585 (162)	0	0		0	0	0	
Airlock Pump	1	0	70.3 (155)	144 (5.0)	~0	1000		0	0	0	provided by Russia
Latching Motor Valve	6	0	1.5 (3.3)	0.4 (0.015)	~0			0	0	0	
Manual Isolation Valve	8	0	1.0 (2.1)	0.1 (0.004)	~0	48		0	0	0	
Pressure Transducer	4	0	0.2 (0.5)	0.1 (0.005)	0.07	0.07		0	0	0	
Pressure Regulator (02, N2, EVA)	3	0	1.7 (3.8)	0.2 (0.01)	0	0		0	0	0	
Relief Valve	4	0	1.6 (3.6)	0.2 (0.01)	0	0		0	0	0	
Oxygen Resupply from Shuttle									227 (500)		
Nitrogen Resupply from Shuttle									227 (500)		
PBA Access Ports											9 sets of 2 QD's

TABLE 20.—*USOS ECLS components (Continued).*

Assembly/ORU	Qty.	Qty. Spares	Mass, kg (lb)	Volume, L (ft3)	Avg. Power, W	Peak Power, W	Replacement Period	Crew Time, MMH/yr.	Ressupply mass, kg/yr (lb/yr)	Ressupply Vol., L/yr (ft3/yr)	Notes
Temperature and Humidity Control (THC)											
CCAA	5		112 (247)	400 (14.1)	468 (@ 450 cfm)	844		~0	0	0	Hamilton Standard
–Inlet ORU	6	2	25.3 (55.8)	130.2 (4.6)	180-776 (@ 300-550 cfm)	776			0	0	
–Condensing HX	5	0	54.45 (120)	108 (3.8)	0	0			0	0	
–Water Separator	5	3	11.9 (26.2)	82.1 (2.9)	44	44			0	0	
–Temp. Control & Check Valve	8	2	7.5 (16.5)	50.9 (1.8)	0.1	15			0	0	
–Electrical Interface Box (EIB)	5	1	4.1 (9.0)	11.3 (0.4)	8	8			0	0	
–Temperature Sensor	5	0	0.24 (0.52)	0.6 (0.02)	0.01	0.01			0	0	
–Liquid Sensor	5	1	0.47 (1.04)	0.6 (0.02)	0.01	0.01			0	0	
–Fan Delta P Sensor	6		0.4 (1.0)	0.2 (0.006)	0.2	0.2			0	0	
–Pressure Sensor	5		0.3 (0.7)	0.06 (0.002)	0.2	0.2			0	0	
IMV Fan	10	2	9.2 (9.3)	9.3 (0.3)	55				0	0	
IMV Valve	29	1	5.1 (11.3)	9.9 (0.35)	6 enabled	20			0	0	Allied-Signal Aerospace Co.
Bacteria Filter Assembly	23		4.6 (10.3) (with HEPA)	121.7 (0.43)	0	0					
–HEPA Filter Element	23	88	2.14 (4.72)	8.2 (0.3)	0	0		2	47 (104)	189 (6.7)	
–Catalytic Filter Element	10	0	5.4 (12.0)	8.2 (0.3	0	0			0	0	
Avionics Air Assembly	6	3	12.4 (27.5)	34.0 (1.2)	50-175 (@40-120 cfm)	175		0	0	0	Hamilton Standard
Atmosphere Revitalization (AR)											
CDRA	2		201 (444)	386 (13.7)	860	1487		2.7	0	0	Allied-Signal Aerospace Co.
–Blower/Precooler	2	1	5.6 (12.3)	25 (0.9)	170	170		0.13	0	0	
–2-Stage Pump	2	1	10.9 (24.0)	4.5 (0.16)	23	245		0.08	0	0	
–Desiccant/Sorbent Bed/ Check Valve ORU	4	1	40 (88)	177 (6.3)	346	960		0.48	0	0	

Table 20.—*USOS ECLS components (Continued).*

Assembly/ORU	Qty.	Qty. Spares	Mass, kg (lb)	Volume, L (ft3)	Avg. Power, W	Peak Power, W	Replacement Period	Crew Time, MMH/yr.	Ressupply mass, kg/yr (lb/yr)	Ressupply Vol., L/yr (ft3/yr)	Notes
–Selector Valve	12	1	3.0 (6.7)	1.7 (0.06)	<1	60		2	0	0	
–Heater Controllers		1 on-orbit	3.3 (7.3)	0.8 (0.3)	19 (active); 10 (passive)	32		0.02	0	0	
–Pump Fan Motor Controller	4	1	2.7 (6.0)	5.7 (0.2)	2	20		0.01	0	0	
TCCS	2		78.2 (172.5)	272 (9.6)	174.6	239		4.37	24.1 (53.0)	340 (12.0)	Lockheed Missiles and Space Company
–Blower	2	1	2.9 (6.5)	5.7 (0.2)	34.5	51.8			0.7 (1.6)	1.4 (0.05)	
–Flowmeter	2	1	1.1 (2.4)	0.3 (0.01)	11.5	11.5			0.3 (0.6)	0.06 (0.002)	
–Charcoal Bed	2	1	37 (81)	76.4 (2.7)	0	0	Once/90 days		18.2 (40)	306 (10.8)	may last longer depending on contaminant load
–Post-sorbent Bed (LiOH)	2	1	4.1 (9.1)	7.9 (0.28)	0	0	Once/90 days		2.1 (4.6)	7.9 (0.28)	may last longer depending on contaminant load
–Catalytic Oxidizer2	2	1	11.1 (24.4)	24.3 (0.86)	121	168	Once/yr		2.8 (6.1)	24.3 (0.86)	
–Electrical Interface Assembly	2	1			7.6	7.6			0	0	
MCA	2		54.7 (120.7)	439 (15.5)	87.6	87.6		0.422	12 (27)	23.2 (0.82)	Orbital Sciences Corp.
–Verification Gas Assembly	2	1	5.4 (12.0)	13.6 (0.48)	0.1		Once/3 yr		3.6 (8.0)	9.0 (0.32)	
–Mass Spectrometer	2	3 total; 1 on-orbit	13.9 (30.7)	23.8 (0.84)	31.8		Once/2 yr		6.9 (15.3)	9.0 (0.32)	
–Sample Pump	2	3 total; 1 on-orbit	3.4 (7.4)	4.5 (0.16)	4		Once/2 yr		1.7 (3.7)	2.3 (0.08)	
–Sample Distribution	2	2	2.1 (4.6)	4.5 (0.16)	0.1				0	0	
–Data & Control	2	1	8.0 (17.6)	14.1 (0.5)	34.9				0	0	
–Low Voltage Power Supply	2	1 on-orbit	5.7 (12.5)	5.4(0.19)	30.8				0	0	
–Chassis	2	0	15.8 (34.9)	23.8 (0.84)	0				0	0	
–Inlet Valve Assembly							Once/10 yr				
–EMI Filter	2	0			1.8				0	0	
Oxygen Generation Assembly	1		113 (250)	0.14 (5)	1470	2350		2	12.7 (28)	0.01 (0.4)	

TABLE 20.—*USOS ECLS components (Continued).*

Assembly/ORU	Qty.	Qty. Spares	Mass, kg (lb)	Volume, L (ft3)	Avg. Power, W	Peak Power, W	Replacement Period	Crew Time, MMH/yr.	Ressupply mass, kg/yr (lb/yr)	Ressupply Vol., L/yr (ft3/yr)	Notes
Sample Delivery System											
–3-way solenoid valve	15	2	2.1 (4.7)	2.3 (0.08)				0	0	0	
–Manual Valve	11	0	0.23 (0.5)	0.6 (0.02)	0	0		0	0	0	
–Sample Probe	4	0	0.27 (0.6)	0.06 (0.002)	0	0		0	0	0	
Fire Detection and Suppression (FDS)											
Portable Fire Extinguisher	7	1	6.8 (15.1) (Full)	40.5 (1.43)	0	0		0	as required	as required	
Fire Detection Assembly	16	2 total; 1 on -orbit	1.5 (3.28)	2.8 (0.1)	1.48	1.48		0.06	0	0	Allied-Signal Aerospace Co.
Portable Breathing Apparatus	12										
Vacuum Services (VS)											
Cold Cathode Transducer	2	2	3.3 (7.3)	2.8 (0.1)	5	<10		~0	0	0	
Pirani Gauge Transducer	2	1	1.1 (2.5)	1.1 (0.04)	1.5	<3		~0	0	0	
Pressure Sensor Assembly	2	1	1.54 (3.4)	0.06 (0.002)	0.6	0.6		~0	0	0	
Load Control Assembly	1	2	10.0 (22)	12.7 (0.45)	30	40		0.1	0	0	
2.5"valve	2	1	4.7 (10.3)	5.7 (0.2)	~0	44		~0	0	0	
1" valve	13	1	1.9 (4.1)	0.8 (0.03)	~0	44		~0	0	0	
Flexible Bellows	19	0	0.5 (1.1)	0.6 (0.02)	0	0		0	0	0	
Tubing Assemblies & Fittings	28	0	78.6 (173) Total	139 (4.9)	0	0		0	0	0	
2.5" Coupler	50	0	7.7 (17) total	5.7 (0.2)	0	0		0	0	0	
1.0" Coupler	63	0	7.4 (16.4) Total	3.4 (0.12)	0	0		0	0	0	
Non-propulsive Vent	1	0	1.8 (3.9)	1.4 (0.05)	0	0		0	0	0	
Flexible Hoses (various)	22	0	0.2 (0.4)	0.2 (0.007)	0	0		0	0	0	

TABLE 20.—*USOS ECLS components (Continued).*

Assembly/ORU	Qty.	Qty. Spares	Mass, kg (lb)	Volume, L (ft3)	Avg. Power, W	Peak Power, W	Replacement Period	Crew Time, MMH/yr.	Ressupply mass, kg/yr (lb/yr)	Ressupply Vol., L/yr (ft3/yr)	Notes
Water Recovery and Management (WRM)											
Water Processor	1	not yet defined	476 (1050)	1.5 racks	300	800		6	478 (1054) (Includes unibeds (312 kg/yr), particu-late filters (141 kg/yr), ion exchange beds (25 kg/yr))		
Process Control Water Quality Monitor	1	not yet defined	38 (85)	51 (1.8)	30	80		1	negligible	negligible	
–Solid Phase Acidifier							>90 days				Or when internal verification indicates the need for replacement
Urine Processor	1	not yet defined	128 (282)	368 (13)	91 (397 on; 28 Standby	600		13	175 (386) Brine Tanks	2178 (79)	
Commode/Urinal	1	not yet defined	50 (110)	waste mgmt. compartment	72	455		60	435 (959) (Incl-udes canisters, fecal bags, commode and urine odor/ bacteria filters, plenum filters, and urine pretreat)	3364 (128)	
Condensate Tank	1	0	21.2 (46.8	103 (3.6)	<5	<5		0	0	0	
Fuel Cell Tank	4 (est.)	0	21.2 (46.8)	103 (3.6)	<5	<5		0	0	0	
Fuel Cell Water from Shuttle									684 (1508)		
EVA Support											
Airlock CO2 Removal Unit											
–Regenerator	1	0	45.3 (100)	170 (6.0)	397 W avg. ON; 57 W weekly avg.	691			0	0	
–LiOH Canisters	10		13.6 (30)	5.7 (0.2)	0	0			~0	~0	

3.0 ECLS Technologies

The subsystems and the technologies that perform the ECLS functions on the USOS are described in this section.

3.1 Atmosphere Control and Supply (ACS)

The ACS subsystem performs the following functions:

- Pressure control and monitoring to maintain atmospheric pressure and composition by:
  - Controlling *ISS* atmospheric total and O_2/N_2 partial pressures.
  - Providing over- and under-pressure relief of a module.
  - Providing the capability to evacuate the atmosphere of a single module.
  - Providing manual pressure equalization capability at module interfaces.
- Internal distribution of O_2 and N_2 to *ISS* systems, crew, and payload interfaces at the desired temperatures, pressures, and flowrates.

The ACS system interfaces are shown in figure 26 and the distribution of the ACS subsystem throughout the USOS is shown in figures 27 through 33.

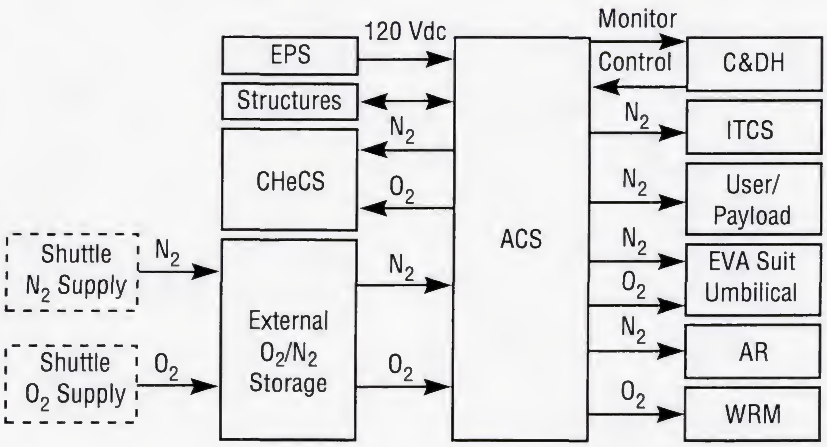
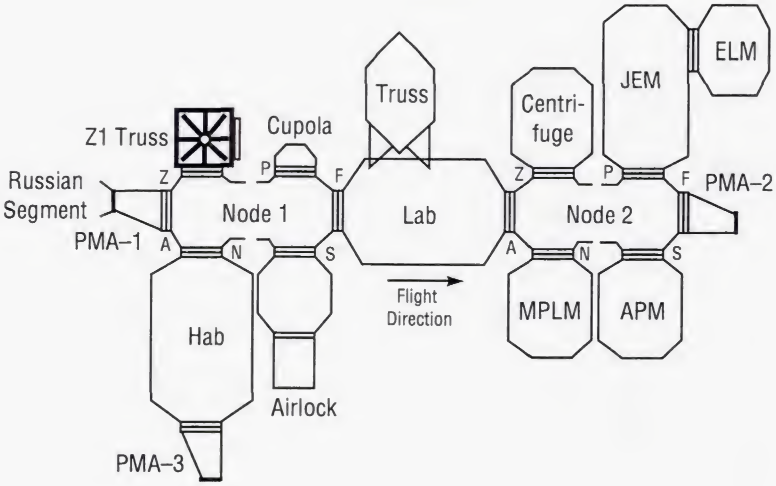


FIGURE 26.—ACS subsystem interfaces.

Legend



- Self-Sealing Quick Disconnect, Half
- Self-Sealing Quick Disconnect, Half With Check Valve
- Flex Hose
- Feedthrough
- Mechanical Fitting, Half
- Manual Valve With Manual Interfaces on Both Sides and Fluid Indication
- Pressure Sensor
- Solenoid Valve with Manual Overide and Position Indication
- Non-Propulsive Vent
- CPS Cabin Pressure Sensor
- VAJ Vacuum Access Jumper
- FC Firmware Controller
- PCP Pressure Control Panel Subassembly
- VRV Vent Relief Subassembly
- PCA Pressure Control Assembly
- NIA Nitrogen Interface Assembly
- Check Valve
- Pressure Regulator
- Relief Valve
- Tank
- Manual Valve
- Motor Valve and Position Indication
- Motor Valve With Manual Overide and Position Indication
- Pump
- Burst Disk
- Diffuser
- Orifice
- Heater
- Temperature Sensor
- O_2
- N_2
- O_2 Recharge
- N_2 Recharge
- A Aft
- F Foward
- N Nadir
- P Port
- S Starboard
- Z Zenith

FIGURE 27.—ACS subsystem.

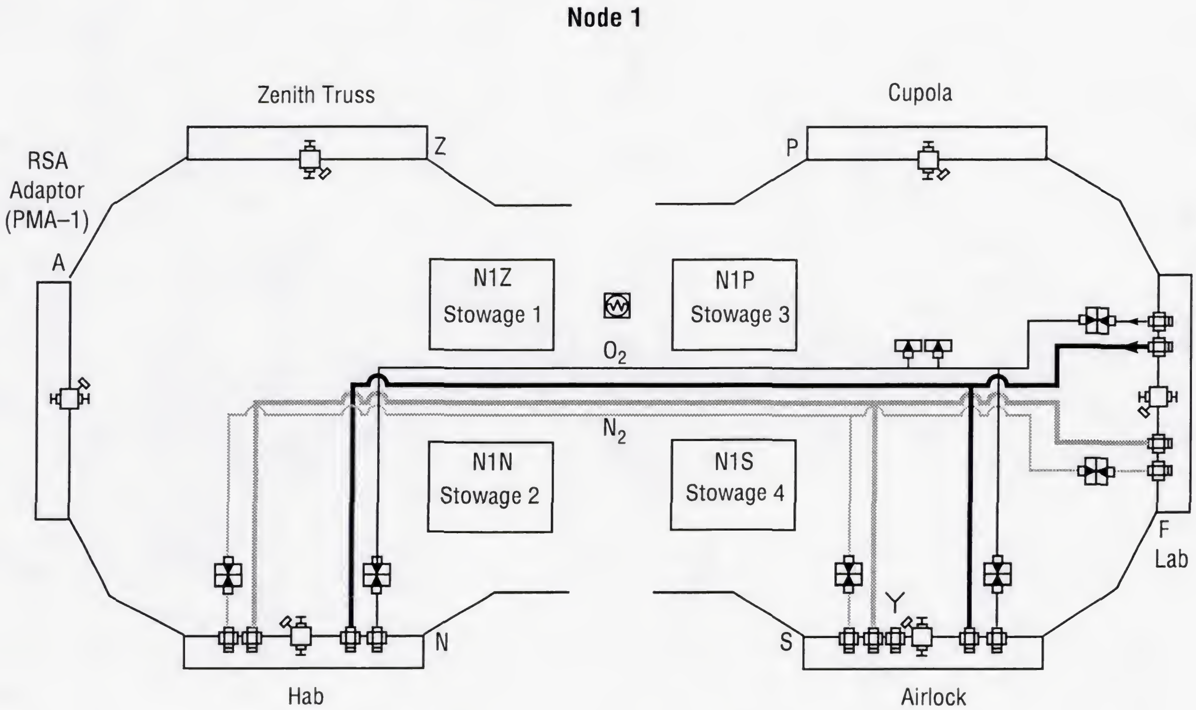


FIGURE 28.—ACS subsystem (continued).

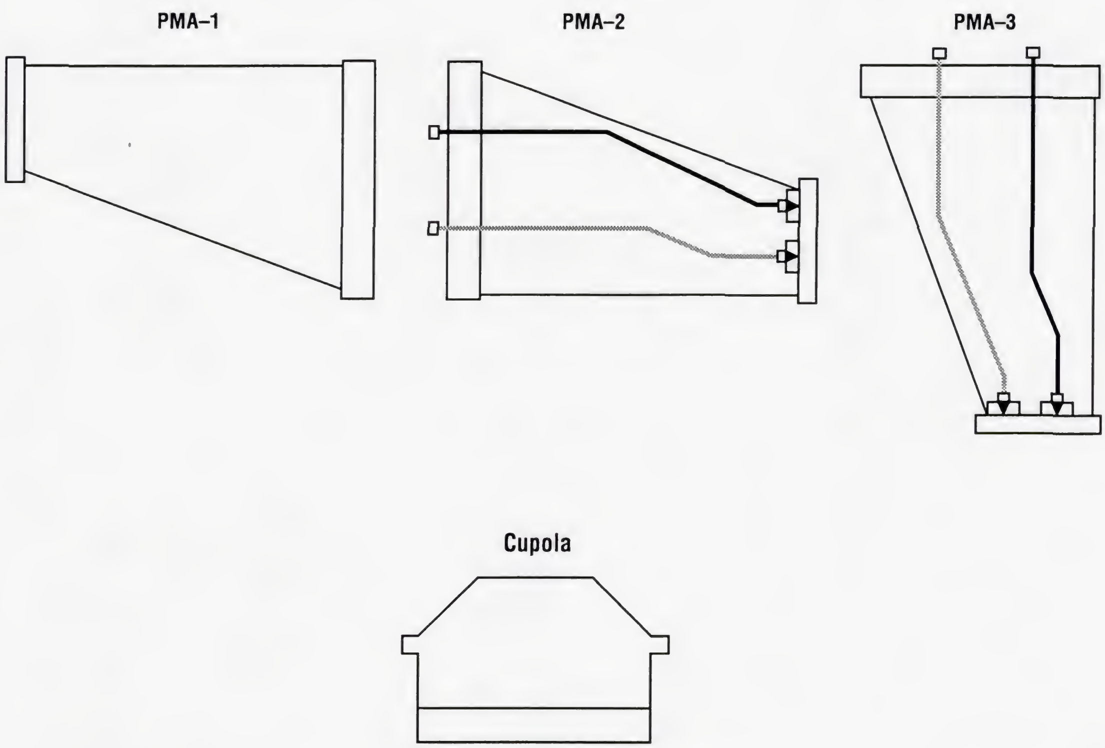


FIGURE 29.—ACS subsystem (continued).

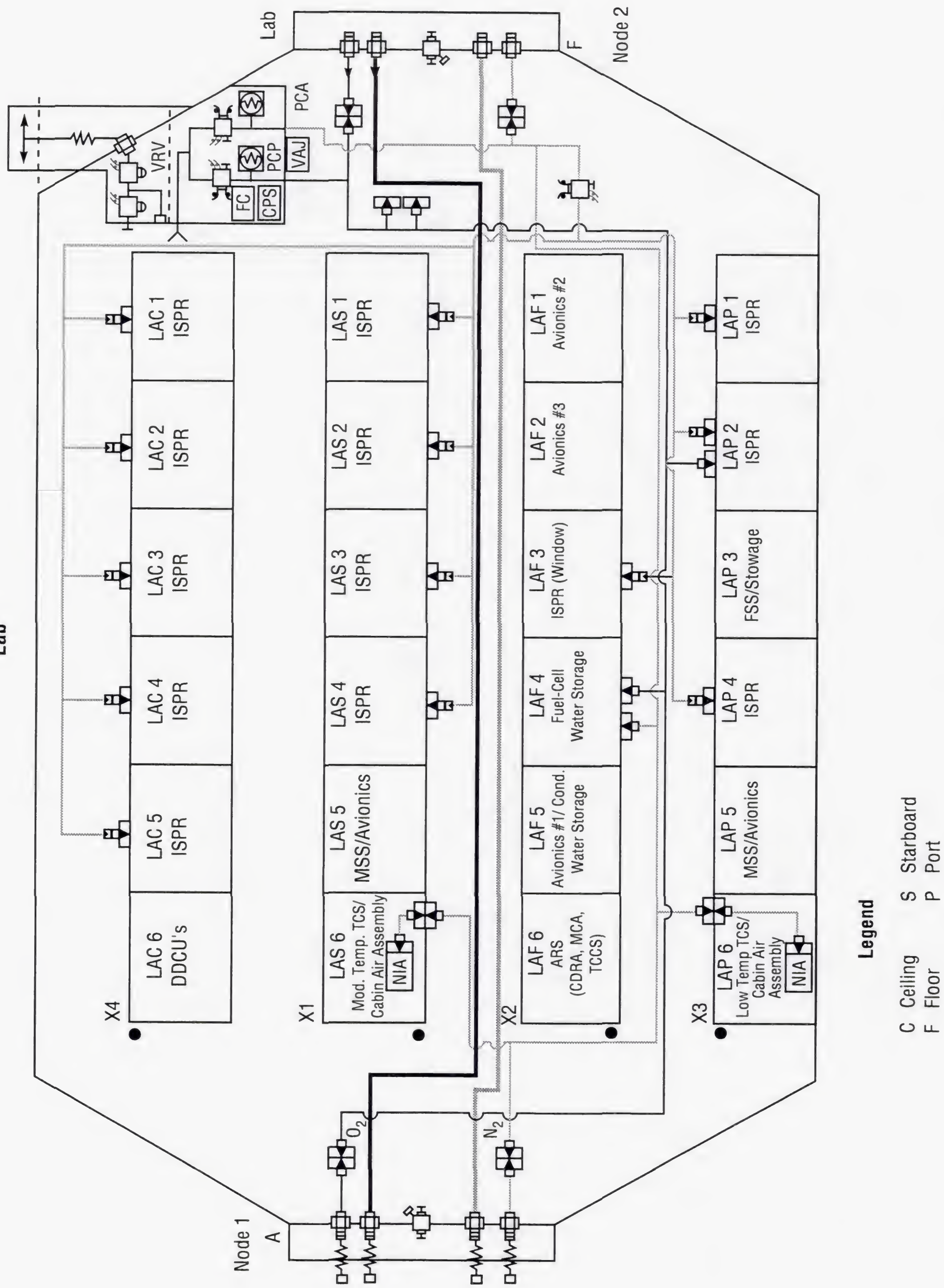
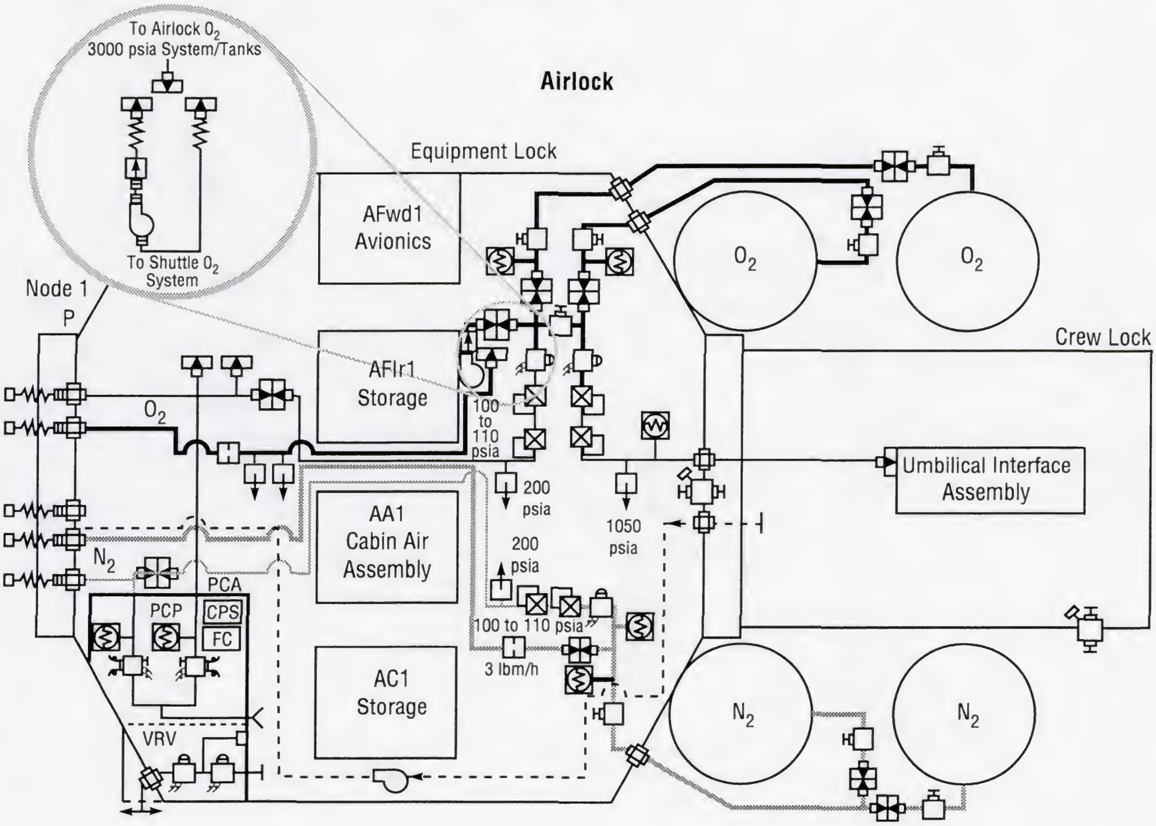


FIGURE 30.—ACS subsystem (continued).

Airlock



Centrifuge

FIGURE 31—ACS subsystem (continued).

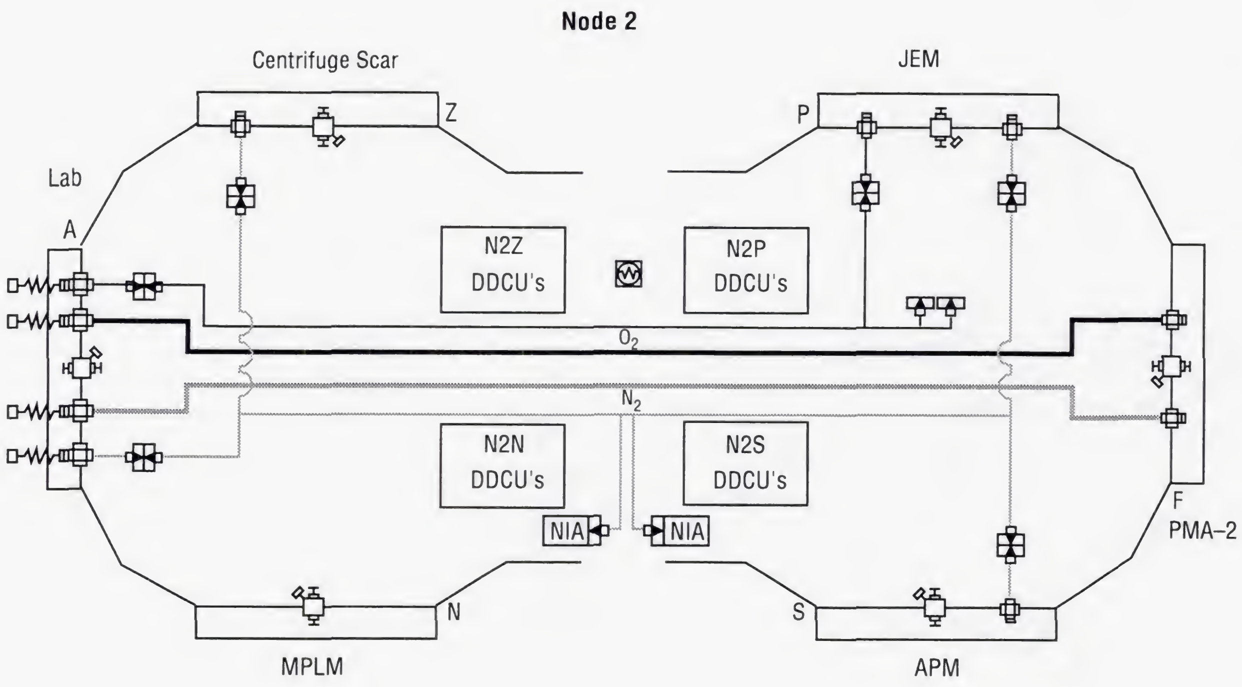


FIGURE 32.—ACS subsystem (continued).

The ACS consists of the following components:

(1) Pressure Control Assembly (PCA)

The PCA monitors and controls total habitat pressure by controlling O_2 and N_2 partial pressures. It provides for controlled venting to space and provides controlled re-pressurization capability. One PCA per module is located in the Lab, Hab, and AL modules. The PCA is shown schematically in figure 34.

The PCA consists of four major components:

- Pressure Control Panel (PCP), which includes:
  - A firmware controller
  - A cabin pressure sensor
  - One each O_2 and N_2 line pressure sensor
  - One each O_2 and N_2 isolation valve (OIV and NIV)
  - An O_2/N_2 discharge diffuser
  - Two O_2/N_2 flow restrictors
- Vent and Relief Valve (VRV) assembly
- Overboard vent
- PCA application software.

The PCA performs seven major functions:

- Cabin pressure monitoring
- O_2/N_2 introduction
- Emergency vent
- Controlled depressurization
- Controlled repressurization
- Space vacuum access
- Positive Pressure Relief (PPR).

The PCP, shown schematically in figure 35, controls the total atmospheric pressure and the partial pressures of O_2 and N_2. The flow restrictors limit the maximum flowrate of O_2 or N_2 into the atmosphere to 0.09 kg/min (0.2 lb/min). The PCP sends a signal through a multiplexer/demultiplexer (MDM) to the onboard computer. Control of the vent and relief valves is also from the PCP. The PCP mass is 11.2 kg (24.8 lb).

The PCP firmware controller provides electrical power distribution and data processing for the PCA. All PCA sensors interface to the PCA firmware controller and all PCA valves are electrically actuated by the PCA firmware controller.

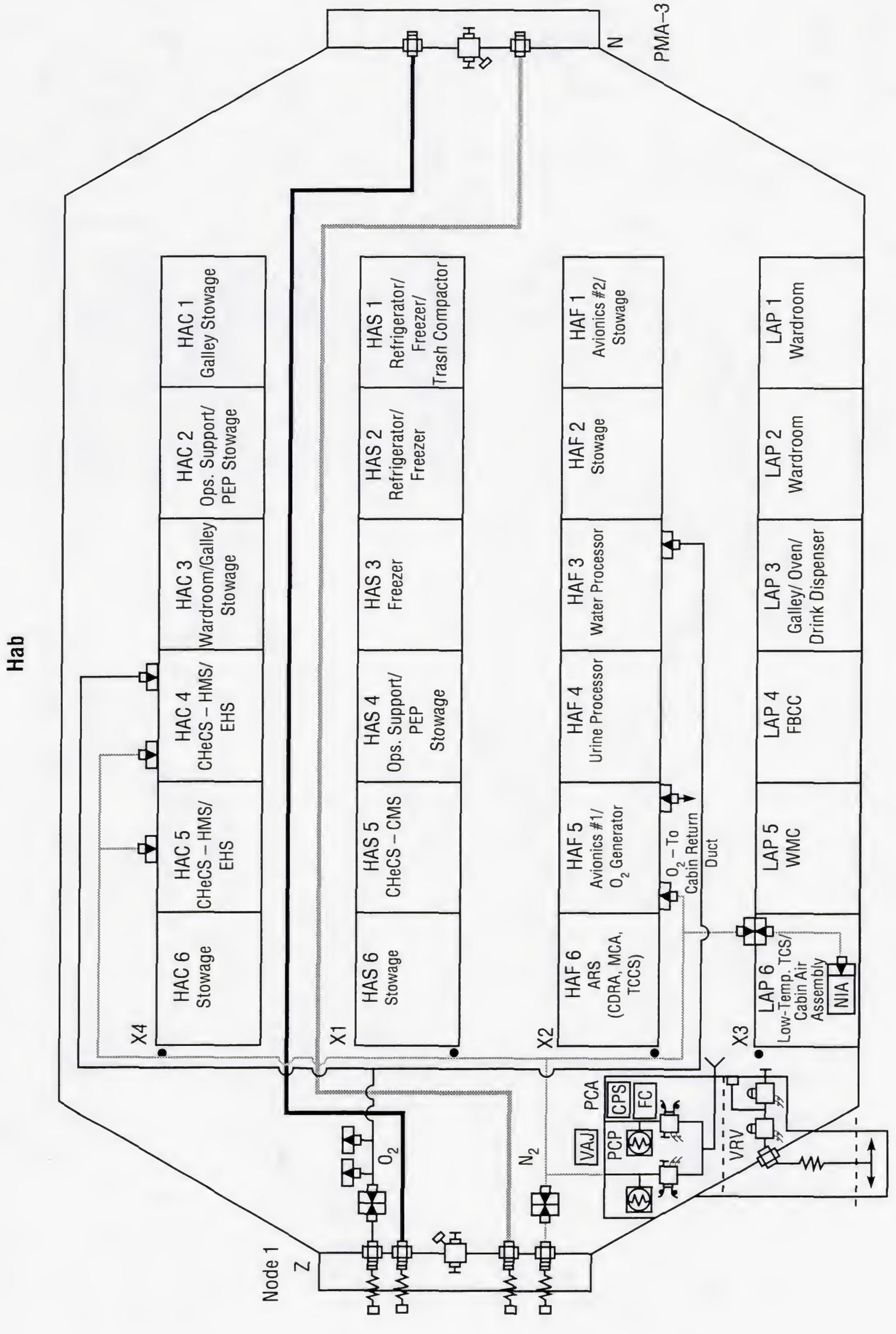
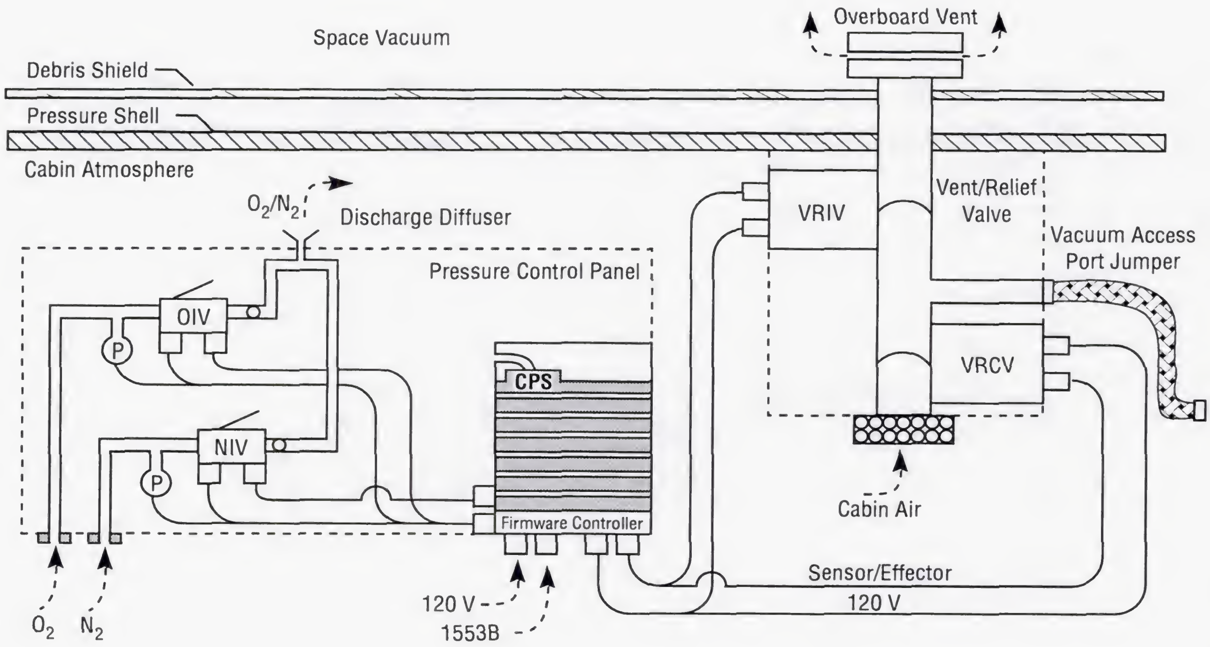


FIGURE 33.—ACS subsystem (continued).



CPS	Cabin Pressure Sensor
VRIV	Vent and Relief Isolation Valve
VRCV	Vent and Relief Control Valve
OIV	Oxygen Interface Valve
NIV	Nitrogen Interface Valve
P	Pressure Sensor

FIGURE 34.—ACS PCA and vent/relief valve assembly.

(2) O_2 and N_2 Storage and Distribution

The O_2 and N_2 storage and distribution hardware consists of storage tanks, valves, QD's, and distribution lines to permit controlled delivery of pressurized O_2 and N_2 to the required locations in the *ISS*. The gases are stored in high-pressure tanks externally mounted on the AL, as shown figure 31 for the AL ACS.

There are two tanks each for O_2 and N_2 that are about 0.91 m (36 in) in diameter and 1.4 m (55 in) long. Each tank has a volume of 425 L (15 ft^3), and contains about 91 kg (200 lb) of either N_2 or O_2 at 20.7 MPa (3,000 psia). The tanks have a service life of 10 yr, with a minimum of 10 launches in that period. These tanks are refilled from a space shuttle docked to either space shuttle docking port. One O_2 tank is considered to be the high-pressure tank and the other the low-pressure tank. Any tank location can have high-pressure or low-pressure tanks. The low-pressure tank can be refilled from the space shuttle (which stores O_2 cryogenically), whereas the high-pressure tank can be represurized with the high pressure O_2 compressor or be replaced. O_2 is introduced to the cabin atmosphere at a nominal rate of 0.84 kg/person/day (1.84 lb/person/day) to maintain the ppO_2 above 19.5 kPa (2.83 psia). The flowrate is 0.045 to 0.91 kg/min (0.1 to 0.2 lb/min).

O_2 Tank Repressurization

The O_2 Recharge Compressor Assembly (ORCA) is located on the ceiling platform, and eliminates or greatly reduces the need for O_2 tank replacement, by compressing O_2 boiled off from the space shuttle O_2 tanks, thereby resulting in a logistics savings. The ORCA has the following characteristics:

- Mass
  - 102 kg (225 lb)
- Power Consumption
  - 1,000 W maximum continuous

- Dimensions
  - 61 cm length by 53 cm width by 48 cm height (24 in length by 21 in width by 19 in height)
- Noise Generation
  - 65 dB measured 0.6 m (2 ft) away
- Pumping Volume
  - 1.8 kg/h (4 lb/h) (58 strokes/min)
- Lifetime
  - Similar units have operated safely and reliably for more than 20 years

Safety features include:

- Sealed, O_2-compatible lubrication
- Triple-redundant diaphragms
- Explosion-proof, brushless electric motor and controls for operation in an O_2-enriched environment.
- Mufflers/isolation to further reduce the 65 dB noise/vibration
- Very small gas volume (minimal stored energy)

In operation the nominal gas transfer quantity is about 27 kg (60 lb) per flight (5 to 6 h transfer duration) with a maximum of 91 to 136 kg (200 to 300 lb) per flight. It is recommended to operate the O_2 compressor only when no one is in the AL, and with the hatch closed. The preferred operational approach is to top off the tanks each flight rather than once/yr.

For maintenance, the O_2 compressor is made of two parts: Module A and Module B, as shown in figure 36. Module A consists of the compression heads, crankcase, and sealed oil reservoirs; and a battery-powered cycle counter to monitor service life. Module A has a mass of 23 to 34 kg (50 to 75 lb), dimensions of 21 by 31 by 62 cm (8 by 12 by 24 in), and an operational life of 100,000 to 200,000 cycles. Module A is returned to Earth for servicing. Module B consists of the motor, gear drive, and baseplate; and has a mass of 45 to 68 kg (100 to 150 lb) and dimensions of 23 by 31 by 46 cm (9 by 12 by 18 in). Module B requires servicing less frequently than Module A.

The interfaces and conditions are listed in table 21. All interfaces are on the ORCA. All flexible connections (flexhoses, cables, etc.) are supplied on the AL side of the interface.

O_2 Tank Replacement

Replacement would be according to the following scenario:

- When the high-pressure tank is installed it is at 20.7 MPa (3,000 psia).
- As long as feasible, gas is supplied by the low-pressure tank unless higher pressure is needed and gas must be supplied by the high-pressure tank.

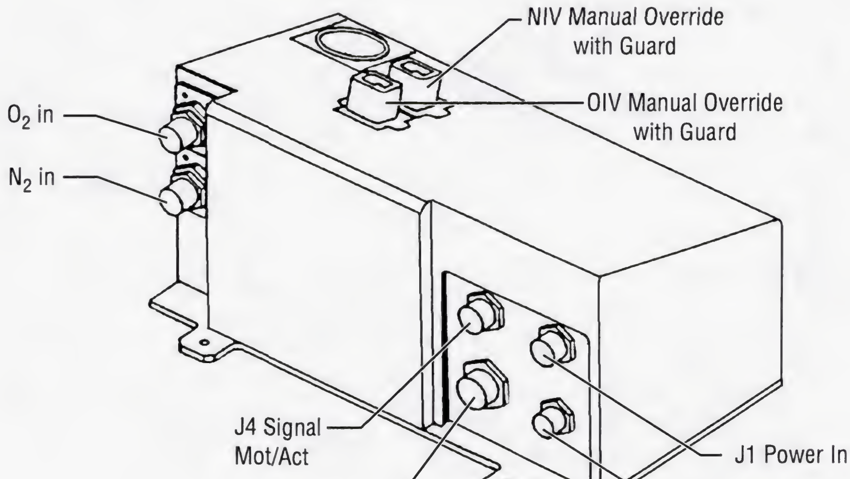


FIGURE 35.—ACS PCP.

TABLE 21.—*ORCA interfaces and conditions.*

AL/ORCA O_2 Interfaces		
	Pressure, MPa (psia)	**Temperature, °C (°F)**
Input	3.4 to 7.2 (500 to 1050)	-4 to 45 (25 to 113)
Output	20.7 (3000) maximum	32 (90) maximum
Minimum Flow Rate	2.3 kg/h at 29 °C and 5.5 MPa in, and 32 °C and 18.6 MPa out (5 lb/h at 85 °F and 800 psia in, and 90 °F and 2700 psia out)	
Maximum Flow Rate	7.3 kg/h (16 lb/h)	
AL/ORCA Air Interfaces		
Input		
	Metric	**US Customary**
Temperature	7.2 to 18.3 °C (requires AL temperature setpoint to be at 18.3°C)	45 to 65 °F (requires AL temperature setpoint to be at 65 °F)
Maximum Flow Rate	4245 L/min with head rise of 7.6 mm H_2O (assumes 0.9 m flex hose from panel)	150 cfm with head rise of 0.3 in H_2O (assumes 3 ft flex hose from panel)
Output		
Maximum Heat Load	1000 W	1000 W

- When the low-pressure tank is empty, valves and gas lines in the AL are reconfigured so that the high-pressure tank becomes the “new” low-pressure tank.
- The old low-pressure tank is removed and a new high-pressure tank is installed at that location.

(3) Manual Pressure Equalization Valve (MPEV)

MPEV’s are located in all the hatches and are used to equalize pressure in two adjacent pressurized modules prior to opening the hatch between them. MPEV’s can also be used to collect atmosphere samples from, and to measure the pressure in, a module prior to opening the hatch by using specially designed MPEV sampling adapters. An MPEV is shown schematically in figure 37.

(4) Nitrogen Interface Assembly (NIA)

The NIA pressurizes the accumulator in the ITCS pump package assembly. One NIA is in the Hab, two are in the Lab, and two are in Node 2. The NIA’s in the Lab and Node 2 serve the ITCS Low-Temperature Loop (LTL) and Moderate-Temperature Loop (MTL). The NIA in the Hab serves the ITCS LTL.

(5) Airlock Air Save Pump Package

The AL air save pump package is provided by the Russians and is located in the AL. It reduces the pressure in the entire AL from 101.3 to 70.3 kPa (14.7 to 10.2 psia) for the EVA campout prior to EVA’s. For EVA’s, it will pump down the crew lock to 3.4 kPa (0.5 psia).

3.1.1 Control Total Atmospheric Pressure

The function of controlling the total atmospheric pressure includes monitoring the pressure and adding N_2 to make up for leakage and other losses.

3.1.1.1 Monitor Total Atmospheric Pressure

The total pressure of the Lab, Hab, and AL atmosphere is monitored by the PCA for control purposes. The pressure is monitored in the range of 0.0 to 110.6 kPa (16.0 psia) with an accuracy of ± 0.07 kPa (0.01 psia) or better. Measurements are updated once each second. If the habitat atmospheric pressure drops below 95.8 kPa (13.9 psia) for longer than 3 min, the crew will be alerted within 1 min.

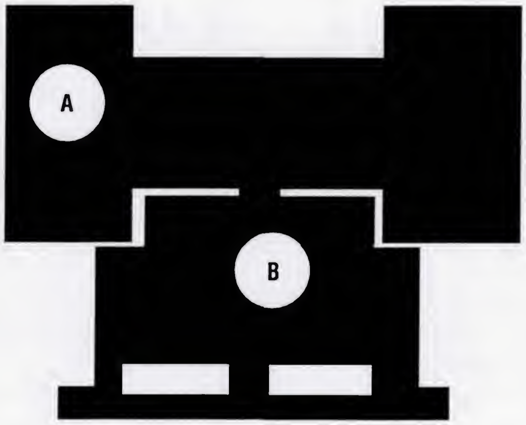


FIGURE 36.—O_2 Compressor Modules A and B.

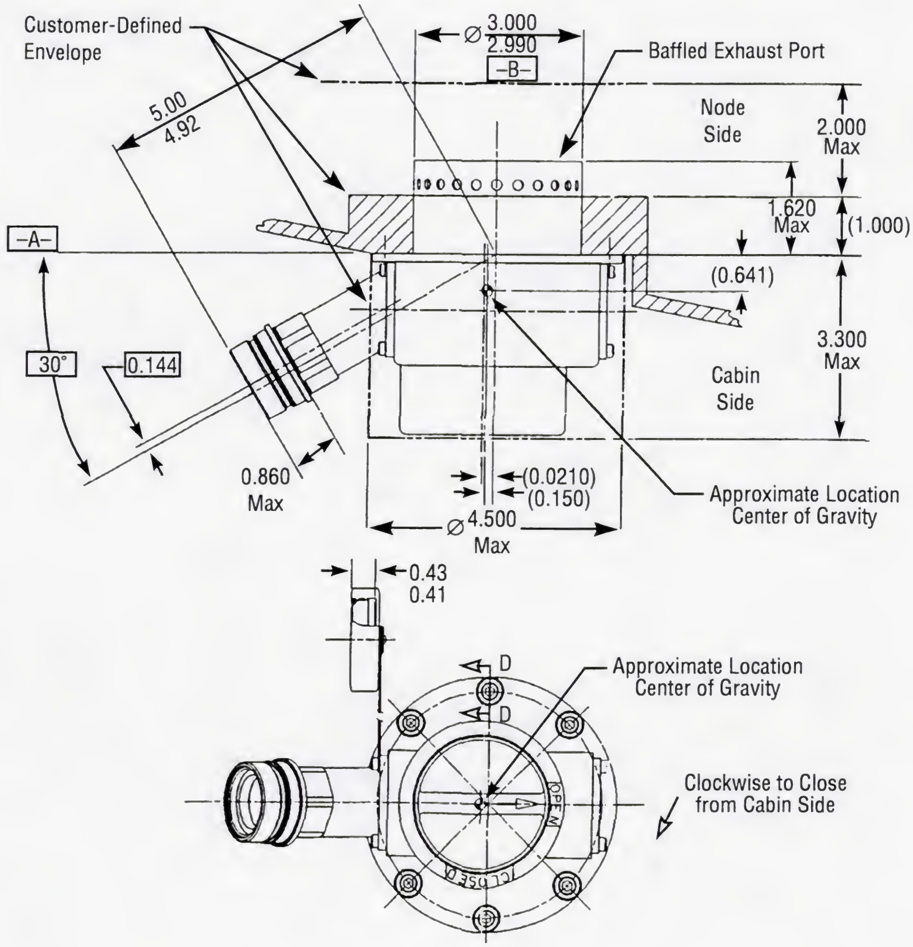


FIGURE 37.—MPEV.

The pressure sensor, shown in figure 38, has a pressure transducer that is a homogeneous quartz structure with a pressure-sensitive diaphragm that acts as a variable capacitance in an oscillator circuit. The oscillation frequency is converted to a digital signal. The pressure readings are temperature compensated.

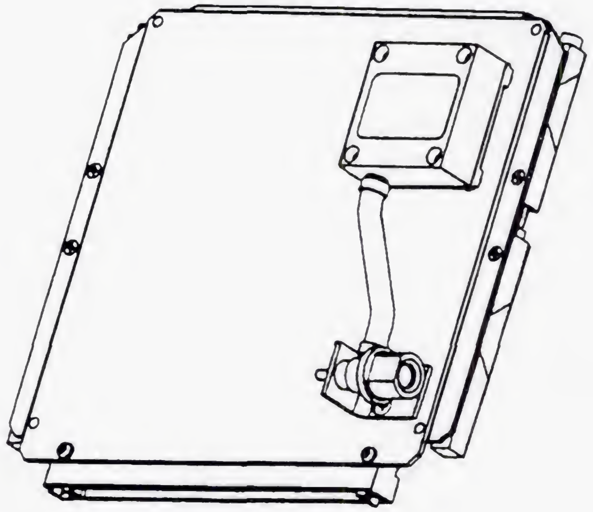


FIGURE 38.—Cabin atmospheric pressure sensor.

3.1.1.2 Introduce Nitrogen

Controlled release of gaseous N_2 into the atmosphere is used to maintain and restore pressure lost due to normal leakage, EVA's, and other loss of atmosphere to space. Gaseous N_2 is supplied to the Lab, Hab, and AL for this purpose. Remote and manual on/off control of the introduction of N_2 into the atmosphere is provided. The rate of flow is 0.045 to 0.091 kg/min (0.1 to 0.2 lb/min). The capability is present to maintain the total atmospheric pressure greater than 97.8 kPa (14.2 psia), though the N_2 partial pressure is not to exceed 80.0 kPa (11.6 psia) and the total pressure is not to exceed 102.7 kPa (14.9 psia). The Lab is capable of maintaining the atmospheric pressure for the entire *ISS* when in an open-hatch, active-IMV configuration, or in the Lab when in a closed-hatch, closed-IMV configuration. Beginning with Flight 7A, transfer lines from the tanks on the AL to PMA–2 (and PMA–3, later) allow for recharging the tanks from the space shuttle. These are 23.4 MPa (3,400 psia) lines.

3.1.2 Control Oxygen Partial Pressure

The function of controlling the ppO_2 includes monitoring the ppO_2 and adding O_2 to make up for consumption, leakage, and other losses.

3.1.2.1 Monitor Oxygen Partial Pressure

The ppO_2 in the atmosphere is monitored by the MCA for control purposes. O_2 is monitored in the range of 0 to 40.0 kPa (0 to 5.8 psia) with an accuracy of ±2 percent of full scale. Atmosphere samples from adjacent modules are provided to the Lab or Hab for analysis.

3.1.2.2 Introduce Oxygen

Controlled release of gaseous O_2 into the atmosphere is used to maintain and restore pressure lost due to normal leakage, EVA's, and other loss of atmosphere to space. Gaseous O_2 is supplied to the Lab, Hab, and AL for this purpose. Remote and manual on/off control of the introduction of O_2 into the atmosphere is provided. The rate of flow is 0.045 to 0.091 kg/min (0.1 to 0.2 lb/min). The capability is present to maintain the ppO_2 above 19.5 kPa (2.83 psia), though the ppO_2 is not to exceed 23.1 kPa (3.35 psia) or 24.1 percent by volume. The Lab, Hab, or AL is capable of maintaining the ppO_2 for the entire *ISS* when in an open-hatch, active-IMV configuration. Beginning with Flight 7A, transfer lines from the tanks on the AL to Node 1 to PMA allow for recharging the tanks from the space shuttle. The transfer lines in the AL are 20.7 MPa (3,000 psia) lines, and the transfer lines in Node 1 and other modules are 7.23 MPa (1,050 psia) lines.

3.1.2.2.1 Oxygen Supply/Generation Assembly

Oxygen is supplied from storage tanks or generated in the Hab by electrolyzing water. Until the Hab is installed, O_2 is provided primarily from the Russian Segment, but also from storage tanks or from the space shuttle. A compressor in the AL is used to compress "boil-off" from the O_2 tanks in a docked space shuttle and recharge the high pressure O_2 tank on the AL.

3.1.2.2.1.1 Oxygen Generation Assembly (OGA) Design

The basic water electrolysis process is shown schematically in figure 39. The detailed design has not been determined as of this writing.

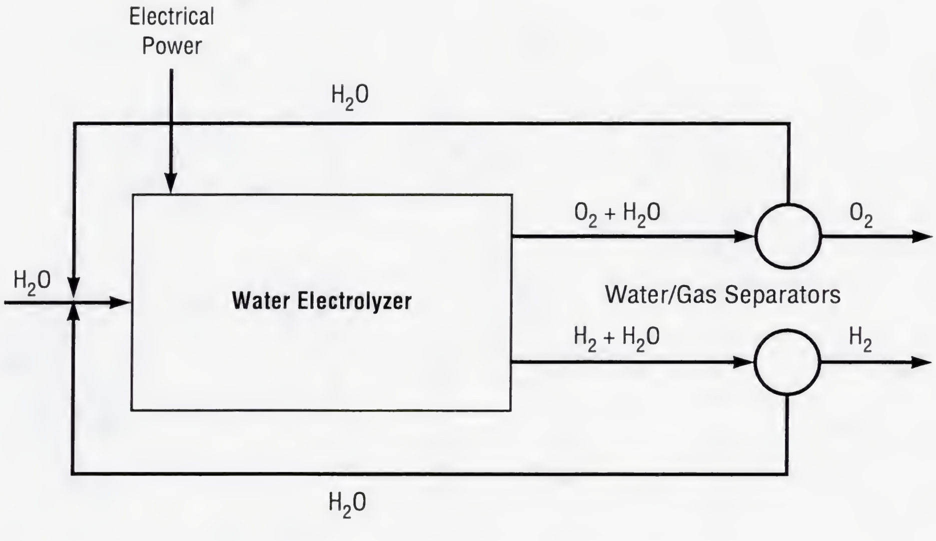


FIGURE 39.—Water electrolysis for oxygen generation.

3.1.2.2.1.2 OGA Operation

The rate of O_2 production is adjustable based on the consumption rate. Features of the system include control by system software and the capability of day/night orbital cyclic operation for night-side power savings.

3.1.2.2.1.3 OGA Performance

The rate of O_2 generation is 5.25 HEU, sufficient for four people, biological specimens, and normal atmospheric losses with day/night cycling. During continuous operation (no day/night power cycle) the capability to support seven people and biological specimens is provided (8.25 HEU total).

3.1.3 Relieve Overpressure

The maximum internal-to-external differential pressure is controlled to be less than 104.8 kPa (15.2 psid). Venting of the atmosphere can occur when the pressure is 103.4 kP a (15.05 psia). The VRV (part of the PCA as shown in fig. 34) is shown in fig. 40. The VRV includes two valves mounted in series in a single housing: the Vent/Relief Isolation Valve (VRIV) and the Vent/Relief Control Valve (VRCV). Each valve is independently powered and controlled. The VRV is 5.6 cm (2.2 in) in diameter and includes an intake designed to preclude blockage of the flow passage with debris. The internal VRV flow passage is a straight cylindrical path that minimizes the possibility of internal flow restriction due to icing. The VRV mounts directly to the gore panel of the primary module structure. The VRV assembly attaches to the gore panel feedthrough with a V-band clamp. The mass of the VRV is < 5.5 kg (12 lb) and the power consumption is less than 30 W when both valves are operating. Leakage is < 72 scc/hr. The estimated life is 25,000 cycles. The VRV can operate over a pressure range of 104.7 kPa (15.2 psia) to space vacuum.

An overboard vent is located downstream of the VRV and provides a 6.4 cm (2.5 in) diameter flow path for discharging vented gases. As shown in figure 41, the overboard vent consists of a 90-degree elbow, a duct assembly, and a non-propulsive vent. The non-propulsive vent has a 22.9 cm (9 in) long throat and a perpendicular 15.2 cm (6 in) diameter disk that causes the gases to be discharged in a full 360-degree arc.

For launch, overpressure and underpressure is relieved by pneumatic valves that are located in the holes for the MPEV and IMV valves, respectively. These valves are replaced, on orbit, with the MPEV and IMV valves.

3.1.4 Equalize Pressure

Pressure equalization is performed using the MPEV to release atmosphere from a higher-pressure module through the hatch into an adjacent lower-pressure module.

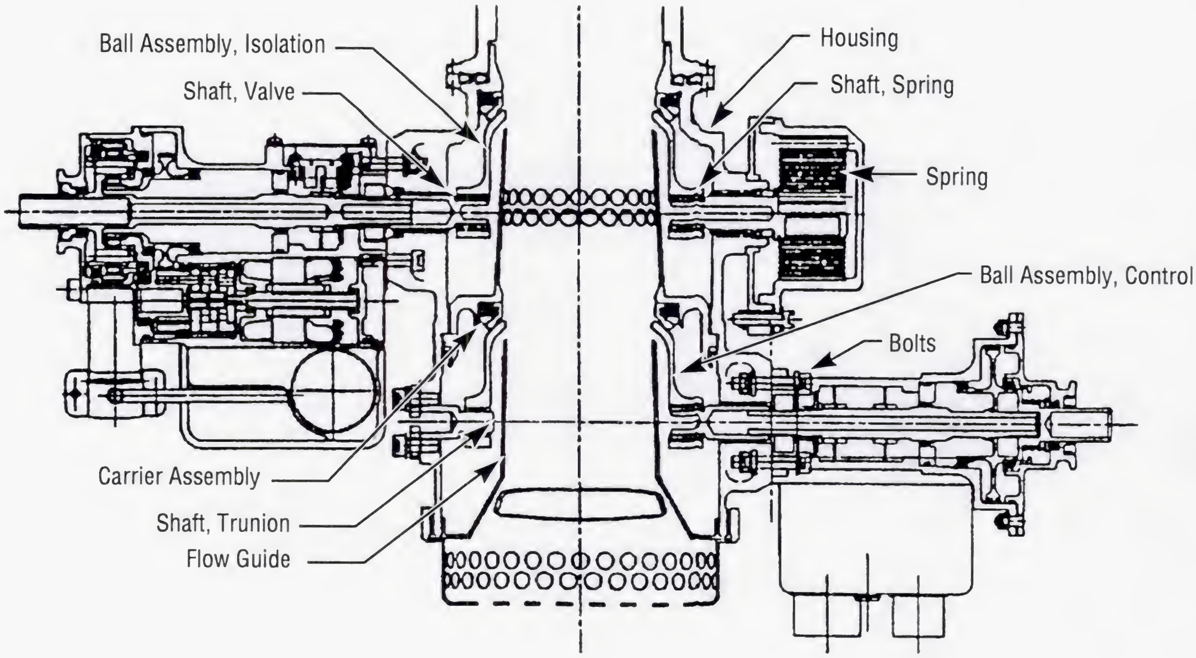


FIGURE 40.—VRV assembly.

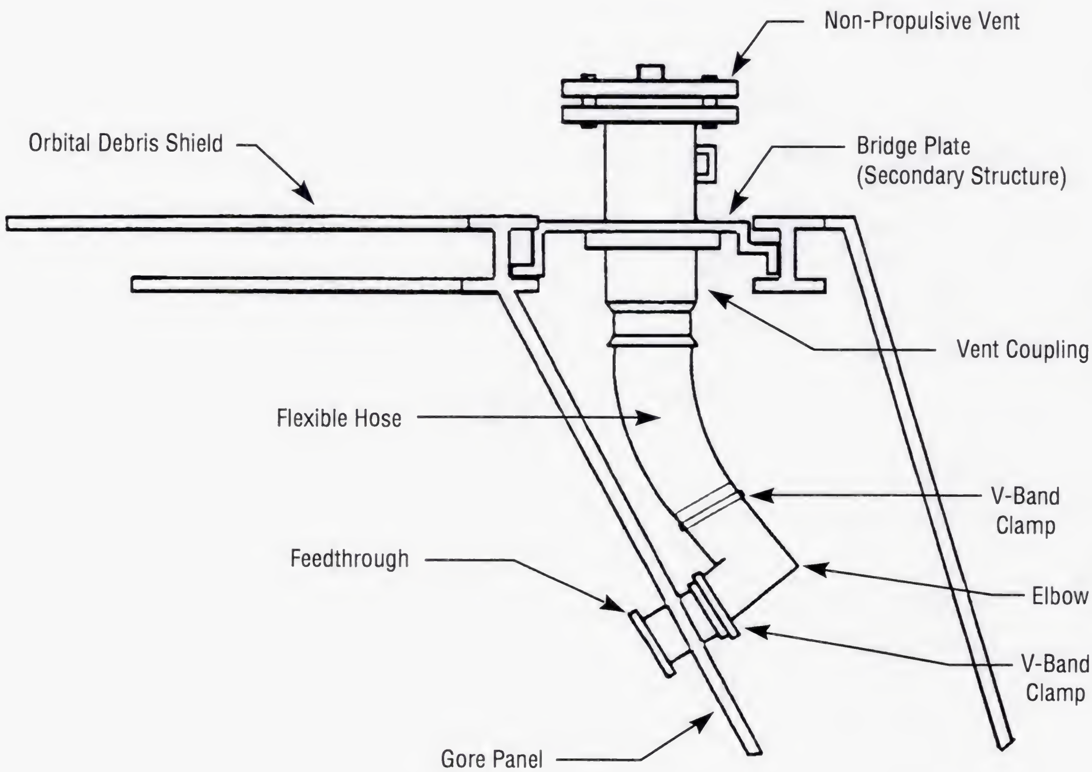


FIGURE 41.—Overboard vent.

3.1.4.1 MPEV Design

The MPEV is shown in figure 37. The module side of the MPEV incorporates a screen, a vacuum access jumper port, and a port cap. The jumper port allows for the temporary connection of a vacuum access jumper. The MPEV inlet port will interface with a standard 2.54 cm (1 in) nonmetallic hose.

3.1.4.2 MPEV Operation

The MPEV is manually operated from either side of the valve and remains in the last position selected. An indicator shows the position of the valve (open, closed, or intermediate). The MPEV is designed to operate for at least 3,650 full-closed to full-open to full-closed cycles.

3.1.4.3 MPEV Performance

The pressure differential between adjacent pressurized modules can be equalized from a high on one side of 102.7 kPa (14.9 psia) to a low on the other side of 97.2 kPa (14.1 psia), to less than 0.07 kPa (0.01 psid) within 180 sec when initiated by the crew.

3.1.5 Respond to Rapid Decompression

The capability to detect and recover from rapid atmospheric decompression (such as caused by a meteoroid impact) is provided. In the event of a module depressurization the instrumentation and software would likely detect this before the crew would. There are separate alarms for excessive dP/dt and for low pressure. There is also a "ΔP" button on the C&W panel (shown in fig. 114) for crew activation of the alarm. The following actions would be automatically initiated:

- IMV valves closed and the IMV fan switched off.
- All external vents closed:
  - Water vent valves in the Lab
  - CO_2 vent valves in the Lab
  - Payload vacuum valves in the Lab
  - PCA relief valves in the Lab, Hab, and AL
- All O_2 and N_2 introduction valves closed.
- CO_2 removal assembly commanded to standby (CO_2 vent closed) or off.

Additional actions that may be performed include:

- Position the SDS valves to prevent atmosphere leakage into depressurizing modules:
  - Leak location may require crew action versus automatic response
  - Command the MCA to standby.
- Switch off hardware if the pressure drops to a specified level. Of concern is the AR hardware, especially fans.

3.1.5.1 Detect Rapid Decompression

Rapid decompression is detected by the firmware controller based on measurements from the cabin pressure sensor.

3.1.5.2 Recover From Rapid Decompression

The ability to repressurize from a total pressure of 86.2 kPa (12.5 psia) to 95.8 to 102.7 kPa (13.9 to 14.9 psia) and an O_2 partial pressure of 19.5 to 23.1 kPa (2.83 to 3.35 psia) within 75 hr is also present, provided that there is sufficient O_2 and N_2 available in the storage tanks. In modules where there are no direct gas line connections to the storage tanks, the MPEV's are used for repressurization.

3.1.6 Respond to Hazardous Atmosphere

During emergency situations, such as contamination of the atmosphere, provisions are in place to ensure survival of the crew. The immediate response for the crew is to don the PBA's, shown in figure 42. The automated response is similar to that for a fire (see section 3.4):

- All USOS IMV valves are closed and fans switched off.
- All cabin atmosphere ventilation is switched off.
- The 4BMS is switched to standby or off (since the ventilation system must be operating for the 4BMS to function properly).
- Further action must be performed by the crew or Ground Control to locate and clean up the toxic release.

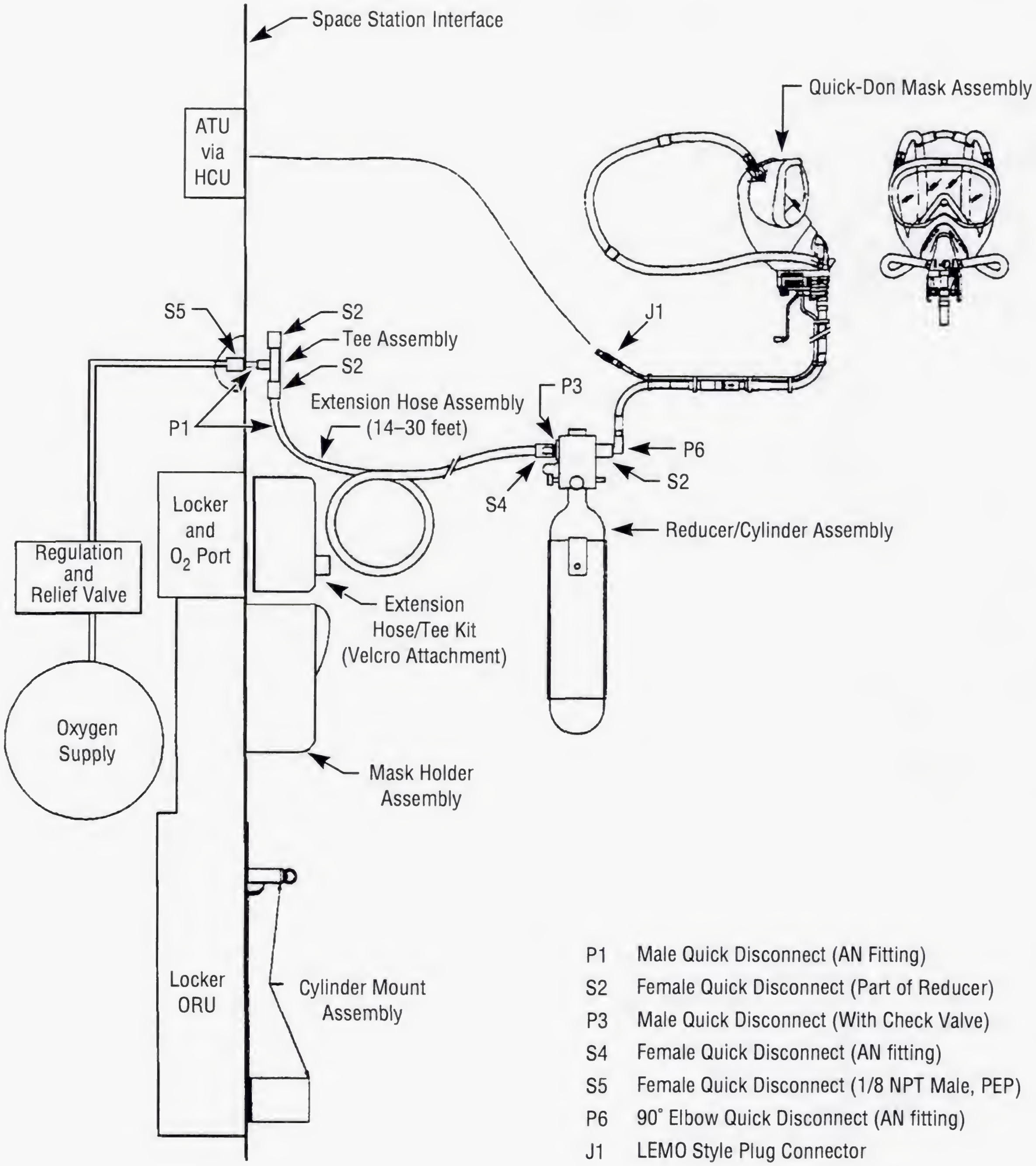


FIGURE 42.—USOS PBA (SSP 50104).

PBA's are face masks with an O_2 supply. Two PBA's are provided in the Lab and Hab, and one in the AL, Node 1, and Node 2. Each PBA provides a 12 to 15 min portable O_2 supply for each crew member. In addition, a 1 hr O_2 supply is provided for each apparatus, through O_2 ports. Two ports are located in each module. (See SSP 50104 for more information.)

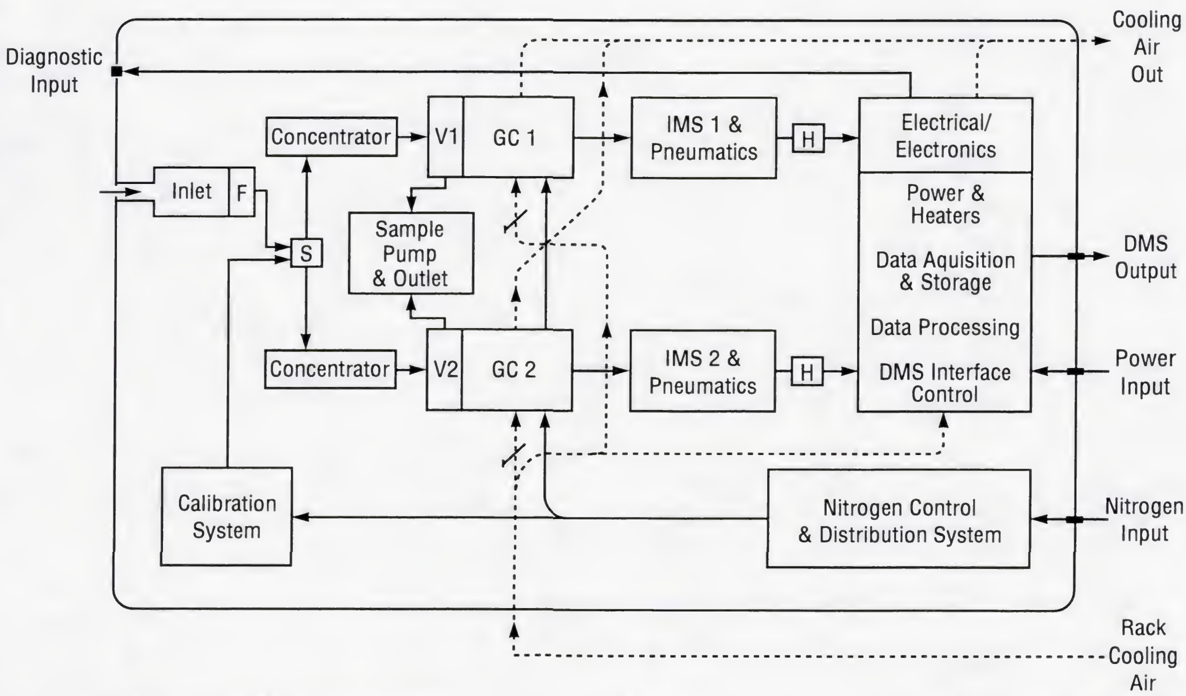
3.1.6.1 Detect Hazardous Atmosphere

In the Lab, the VOA detects Volatile Organic Compounds (VOC) in the atmosphere and alerts the crew if the concentration of any organic compound of interest exceeds the 7-day SMAC. The VOA uses a Gas Chromatograph/Ion Mobility Spectrometer (GC/IMS), as shown in figures 43 and 44, to detect selected organic compounds at concentrations of interest. This capability is provided by the CHeCS. (See also "A Volatile Organic Analyzer for Space Station: Description and Evaluation of a Gas Chromatograph/Ion Mobility Spectrometer," paper 921385, 22nd International Conference on Environmental Systems, 13 to 16 July 1992.)

In the other modules, the crew detects hazardous conditions by the sense of smell or another sense. Some automated capability is provided by the MCA, which monitors for some hazardous gases (H_2 and CH_4). Also, the FDS smoke detectors detect the presence of airborne particulates.

3.1.6.2 Remove Hazardous Atmosphere

Removal of toxic contaminants can be achieved by venting the atmosphere. This can be done either by the crew or remotely from Ground Control. The atmosphere can be vented to space to achieve a pressure of < 2.76 kPa (0.4 psia) within 24 hr. The requirement is also levied to achieve a ppO_2 of < 6.89 kPa (1.0 psia) within 10 min. The procedure for venting atmosphere is described in section 6.4.



DMS	Data Management System	F	Filter	GC	Gas Chromatograph
H		IMS	Ion Mobility Spectrometer	S	Selector Valve
V1, V2	Valves				

FIGURE 43.—VOA block diagram.

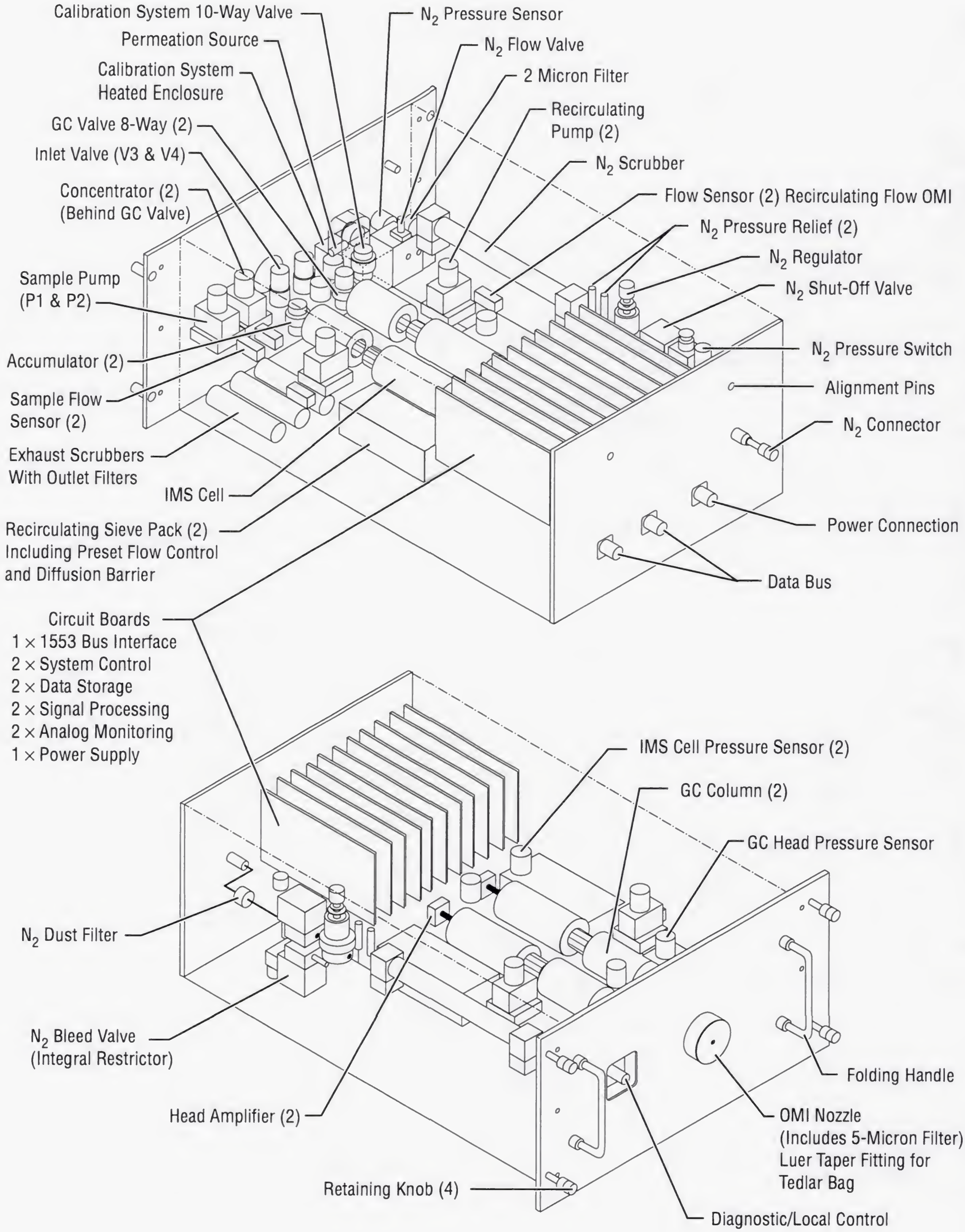


FIGURE 44.—VOA schematic.

3.1.6.3 Recover From Hazardous Atmosphere

To restore a safe atmosphere, the Lab can be repressurized from space vacuum to a total pressure of 95.8 to 102.7 kPa (13.9 to 14.9 psia) and a ppO_2 of 19.5 to 23.1 kPa (2.83 to 3.35 psia) within 75 hr when supplied with gaseous O_2 and N_2. Repressurization is performed either by direct introduction of O_2/N_2 or via pressure equalization with the rest of the *ISS*.

3.2 Temperature and Humidity Control (THC)

The THC subsystem ensures that the temperature and humidity levels in the atmosphere are within the design specifications. Heat enters the atmosphere from the crew (metabolically generated heat) and equipment (lights, etc., although, much of the equipment-generated heat is removed by cold-plates). Humidity enters the atmosphere primarily from crew respiration and perspiration. The THC subsystem includes the CCAA, the AAA, and the IMV assembly. The CCAA provides adequate ventilation, and temperature and humidity control for the cabin. The AAA provides air cooling and air flow required for FDS in the racks. The IMV provides ventilation between modules for distributing oxygen to and removing CO_2 and trace contaminants from modules that do not have ARS and ACS equipment. Particulates and microorganisms are removed from the atmosphere by HEPA filters. The THC interfaces are shown in figure 45. The distribution of the THC subsystem throughout the USOS is shown in figures 46 through 52. The THC rack packaging in rack LAP6 is shown in figure 53. The packaging in rack LAS6 is a mirror image of LAP6.

The requirements that must be met by the THC and the conditions that affect its design and performance are:

- Heat removal capacity
  - 3.5 kW (including 1.0 kW latent capacity)
- Ventilation flowrate
  - 194 L/sec (410 cfm) within the Lab or Hab with 9.4 L/sec (20 cfm) to AR
  - 142 L/s (300 cfm) within Node 1 with the Cupola closed off
  - 66 L/sec (140 cfm) between modules
- Temperature control range
  - 18.3 to 26.7 °C ±4 °C (65 to 80 °F ±2 °F)
- Dewpoint control range
  - 4.4 to 15.6 °C (40 to 60 °F) (RH 25 to 70 percent)
- Coolant flowrate
  - 558 kg/hr (1,230 lb/hr) in the Lab and Hab
  - 273 kg/hr (600 lb/hr) in Node 2 and the AL
- Mass
  - 93.6 kg (206.4 lb)
- Power consumption
  - 467.5 W continuous at 203 L/sec (430 cfm)
- Three settings
  - 142, 208, 264 L/sec (300, 440, 560 cfm).

Major telemetry for the THC includes:

- Software state: Reset, Test, Off, Startup, On, Dryout, Drain, Off
- Temperature setpoint (18.3 to 26.7 °C (65 to 80 °F))
- Primary inlet temperature (4.4 to 32.2 °C, 40 to 90 °F)
- Secondary inlet temperature (4.4 to 32.2 °C, 40 to 90 °F)
- Fan speed (0 to 7,500 rpm)
- Fan dP (0 to 280 mm of water (11 in of water))
- Fan Remote Power Control (RPC) state (open/closed)
- EIB RPC state (Open/Closed)
- TCCV position (0 to 80 degrees)
- TCCV RPC state (Open/Closed)
- Primary outlet temperature (4.4 to 32.2 °C, 40 to 90 °F)
- Secondary outlet temperature (4.4 to 32.2 °C, 40 to 90 °F)
- WS speed sensor (0 to 7,200 rpm)
- WS outlet water pressure (0 to 517 kPa (75 psig))
- WS outlet liquid sensor (–1 to 12 sec)
- WS RPC state (Open/Closed)
- Outlet duct liquid sensor (wet or dry).

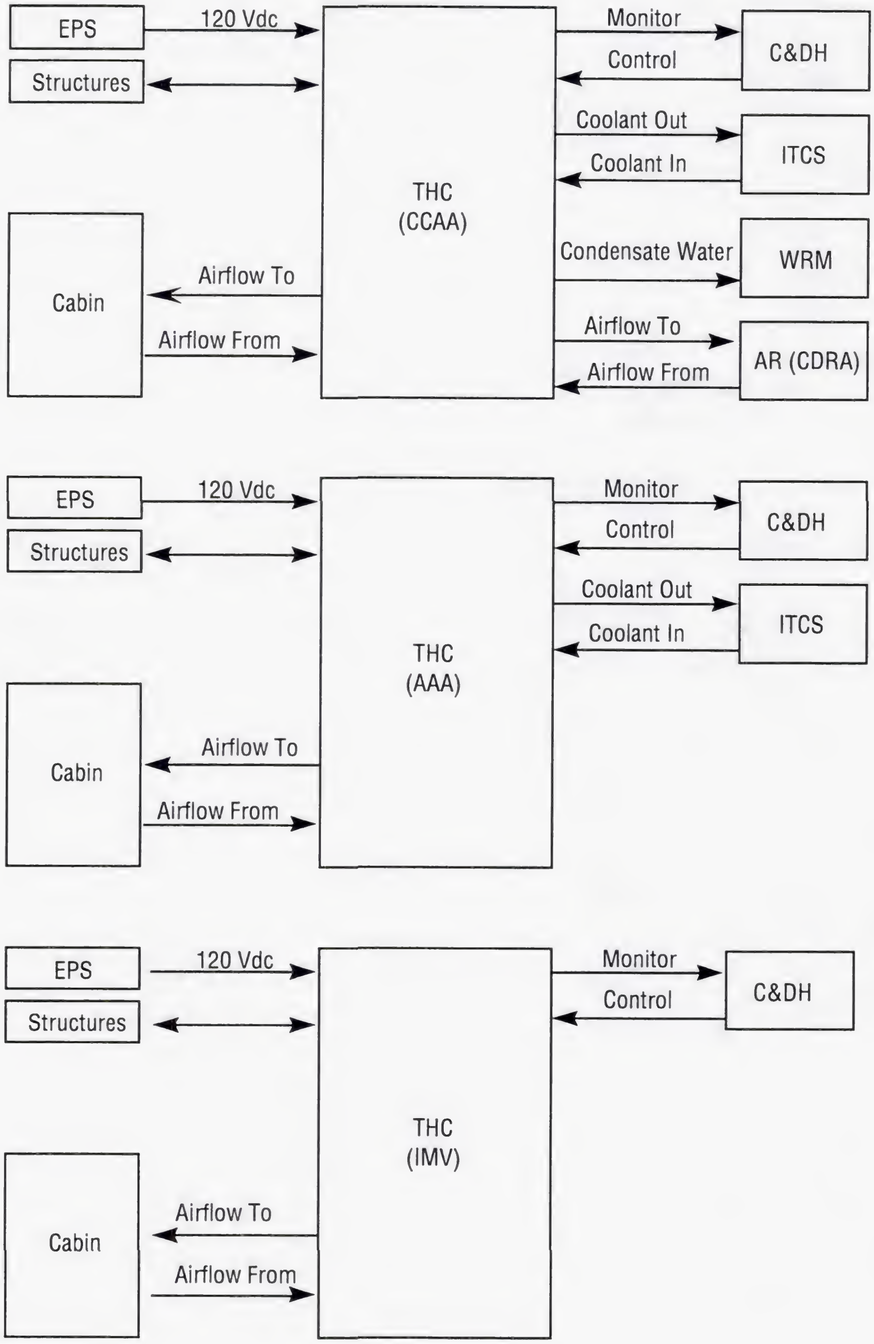


FIGURE 45.—THC subsystem interfaces.

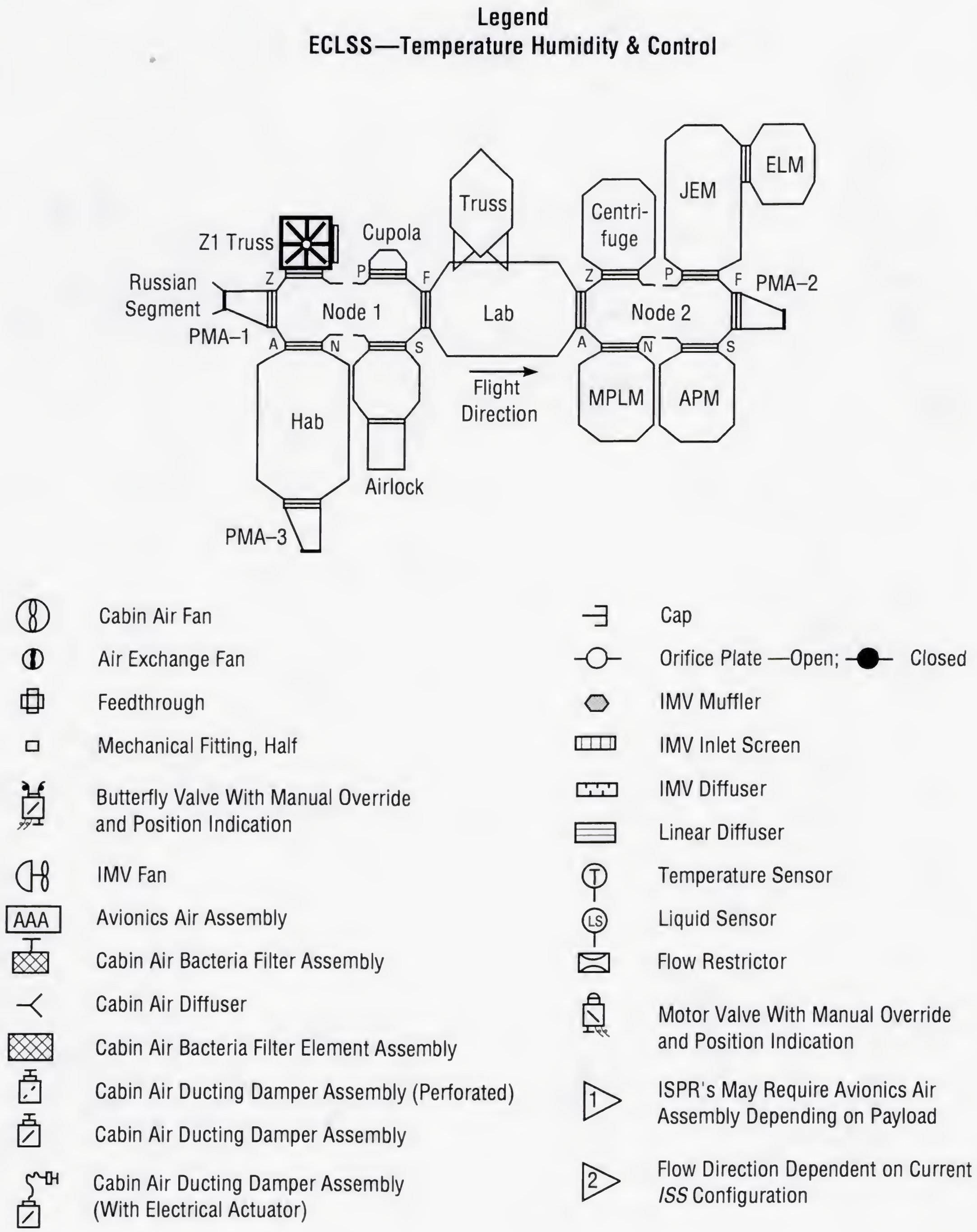


FIGURE 46.—THC subsystem.

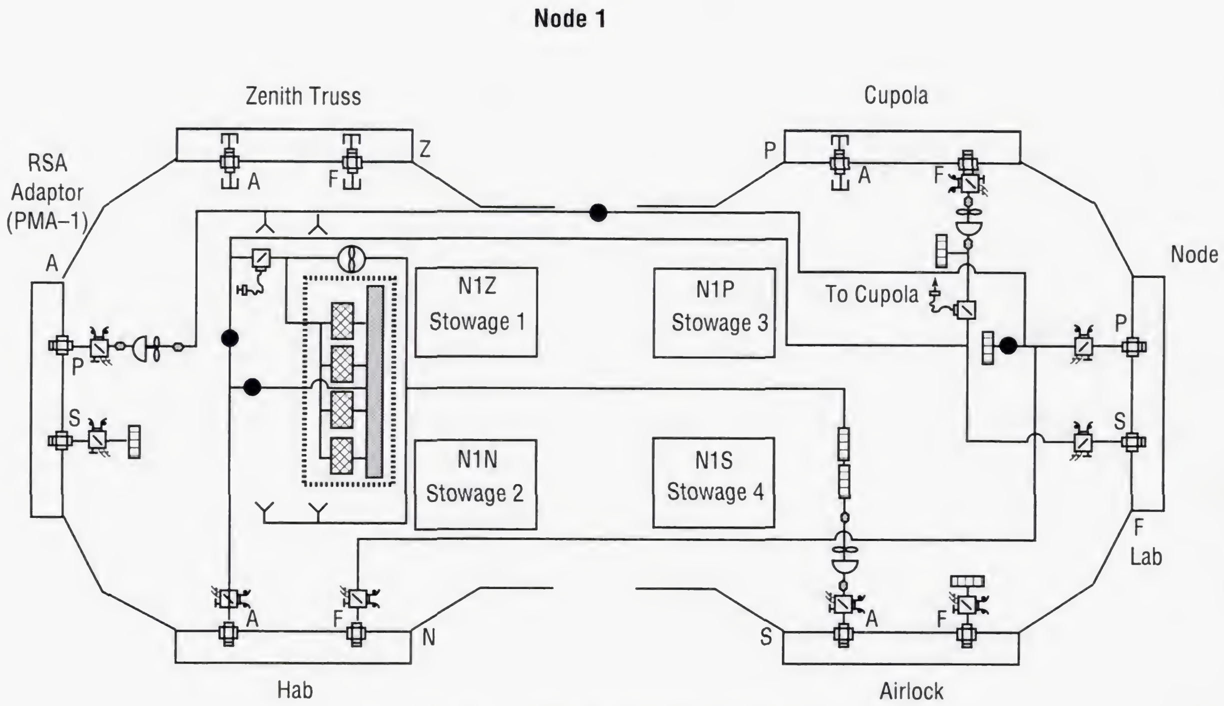


FIGURE 47.—THC subsystem (continued).

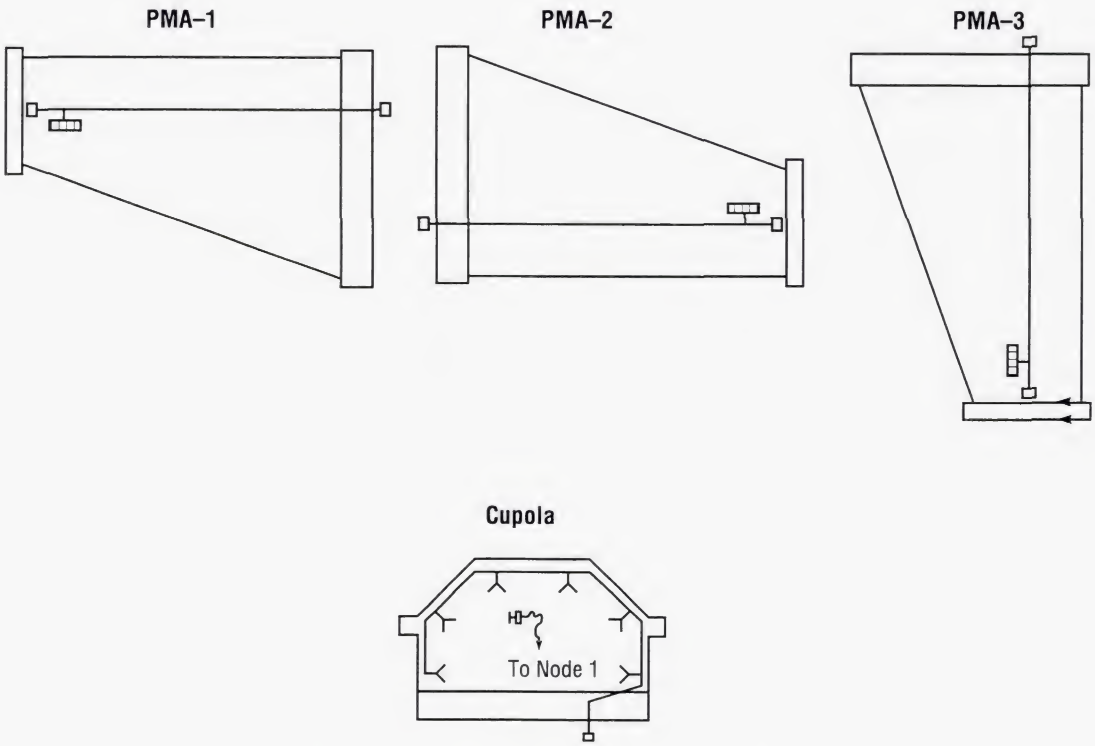


FIGURE 48.—THC subsystem (continued).

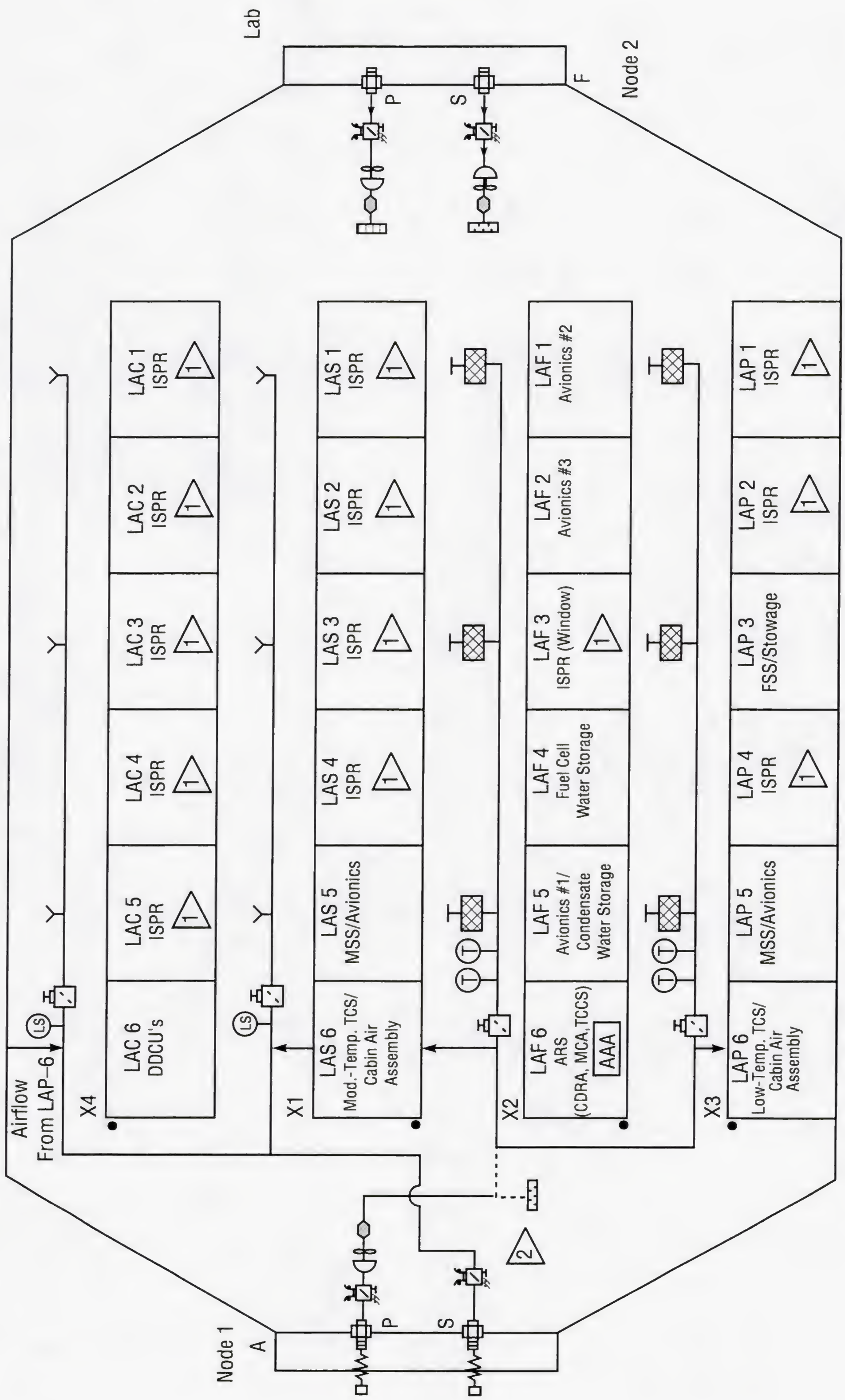
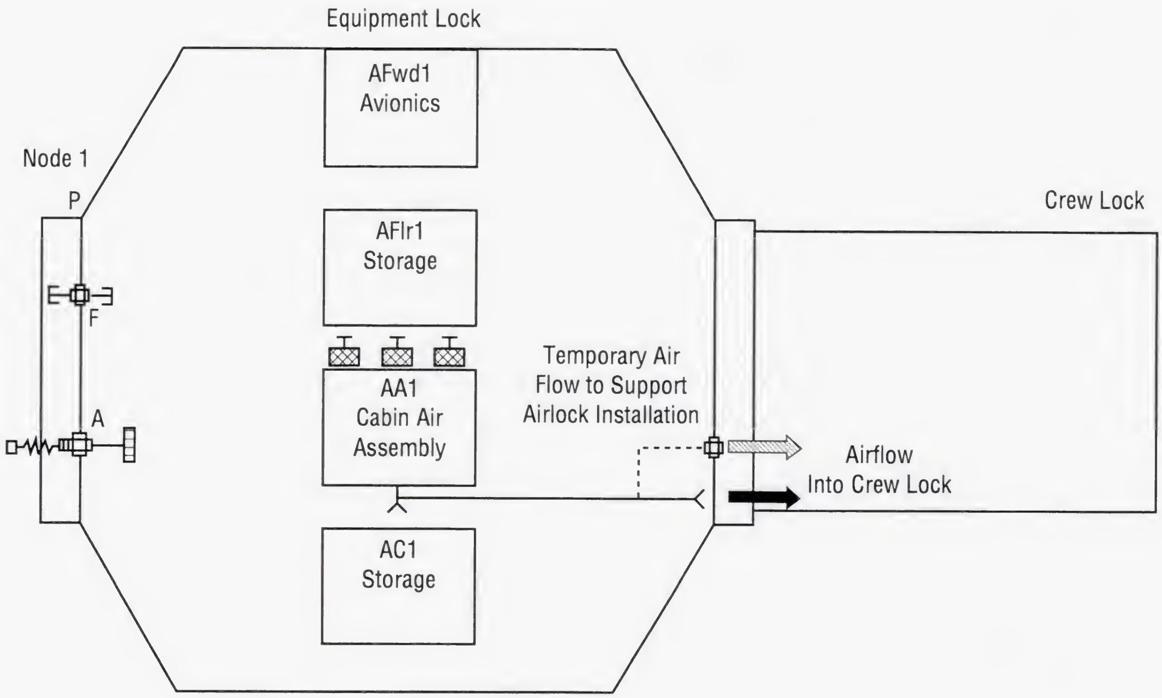


FIGURE 49.—THC subsystem (continued).

Airlock



Centrifuge

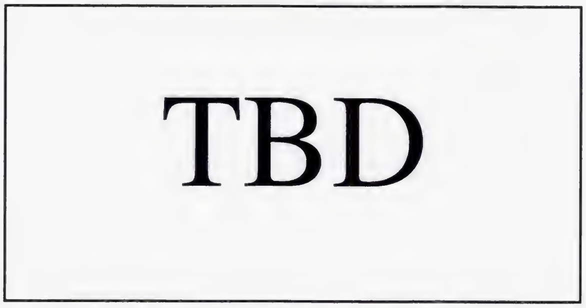


FIGURE 50.—THC subsystem (continued).

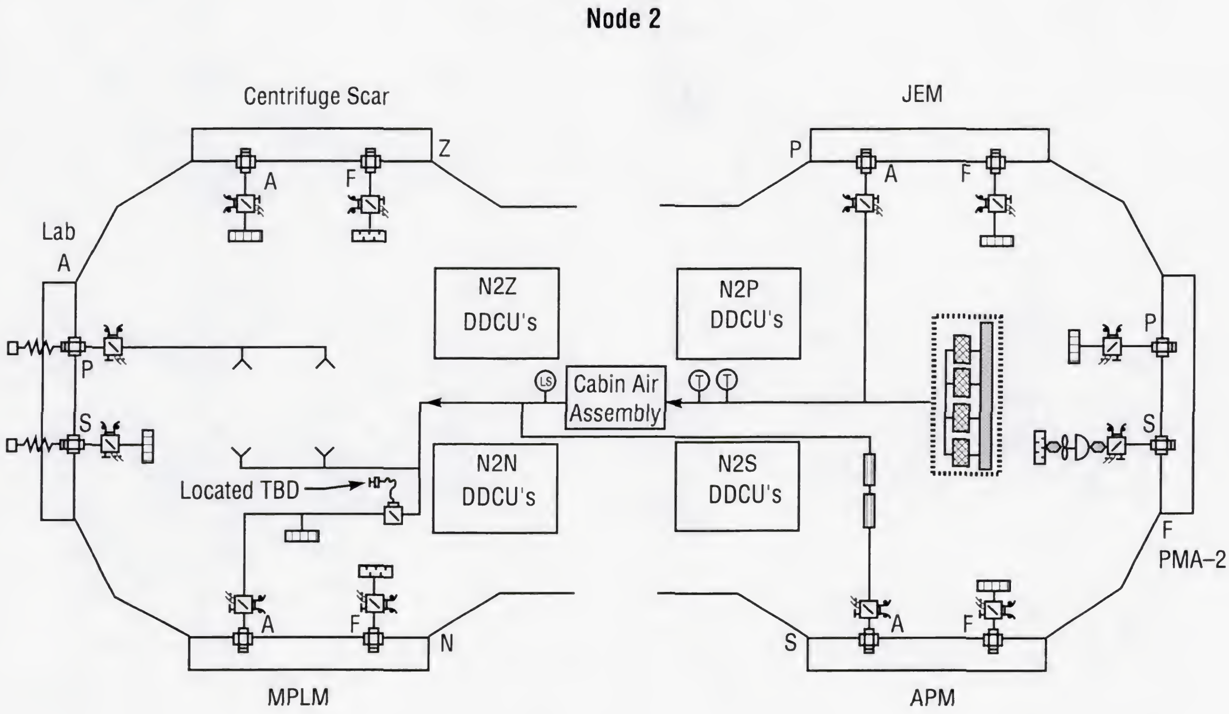


FIGURE 51.—THC subsystem (continued).

3.2.1 Control Atmospheric Temperature

The atmospheric temperature is monitored and maintained within the design limits as described below.

3.2.1.1 Monitor Atmospheric Temperature

The atmosphere temperature is monitored over the range of 15.6 to 32.2 °C (60 to 90 °F) with a Resistance Temperature Detector (RTD) consisting of a wire-wound resistor using platinum, which increases in resistance as temperature increases. The basic construction is shown in figure 54. Four captive fasteners hold the ORU assembly in place. The characteristics of this temperature sensor are:

- Mass
  - 45.5 g (0.1 lb)
- Power consumption
  - 1 mW
- Volume
  - 82 cm^3 (5 in^3)
- Pressure range
  - 34.5 to 104.0 kPa (5.0 to 15.1 psia)
- Temperature range
  - 1.7 to 60 °C (35 to 140 °F)
- Input
  - 1 mA dc
- Output
  - 1,000 ohms ±1.0 ohms at 0 °C (32 °F)
- Accuracy
  - ±0.5 °C (1 °F).

3.2.1.2 Remove Atmospheric Heat

The CCAA's—located in the Lab, Hab, Node 2, and AL—remove excess heat and excess moisture from the atmosphere in order to maintain a safe and comfortable environment for the crew and equipment. Depending on the module heat loads, the atmosphere flowrate can range from 8,490 to 14,150 L/min (300 to 500 cfm).

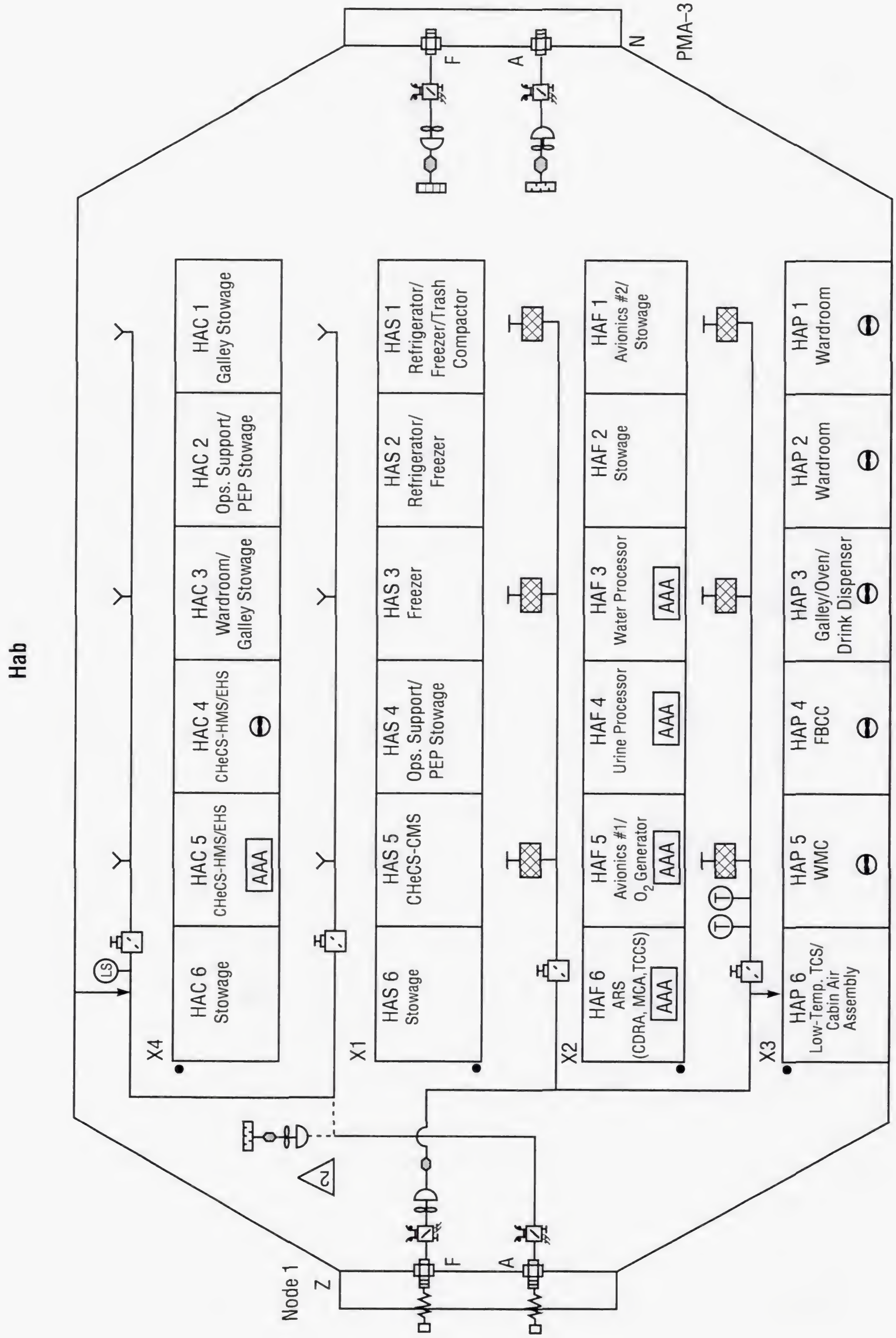


FIGURE 52.—THC subsystem (continued).

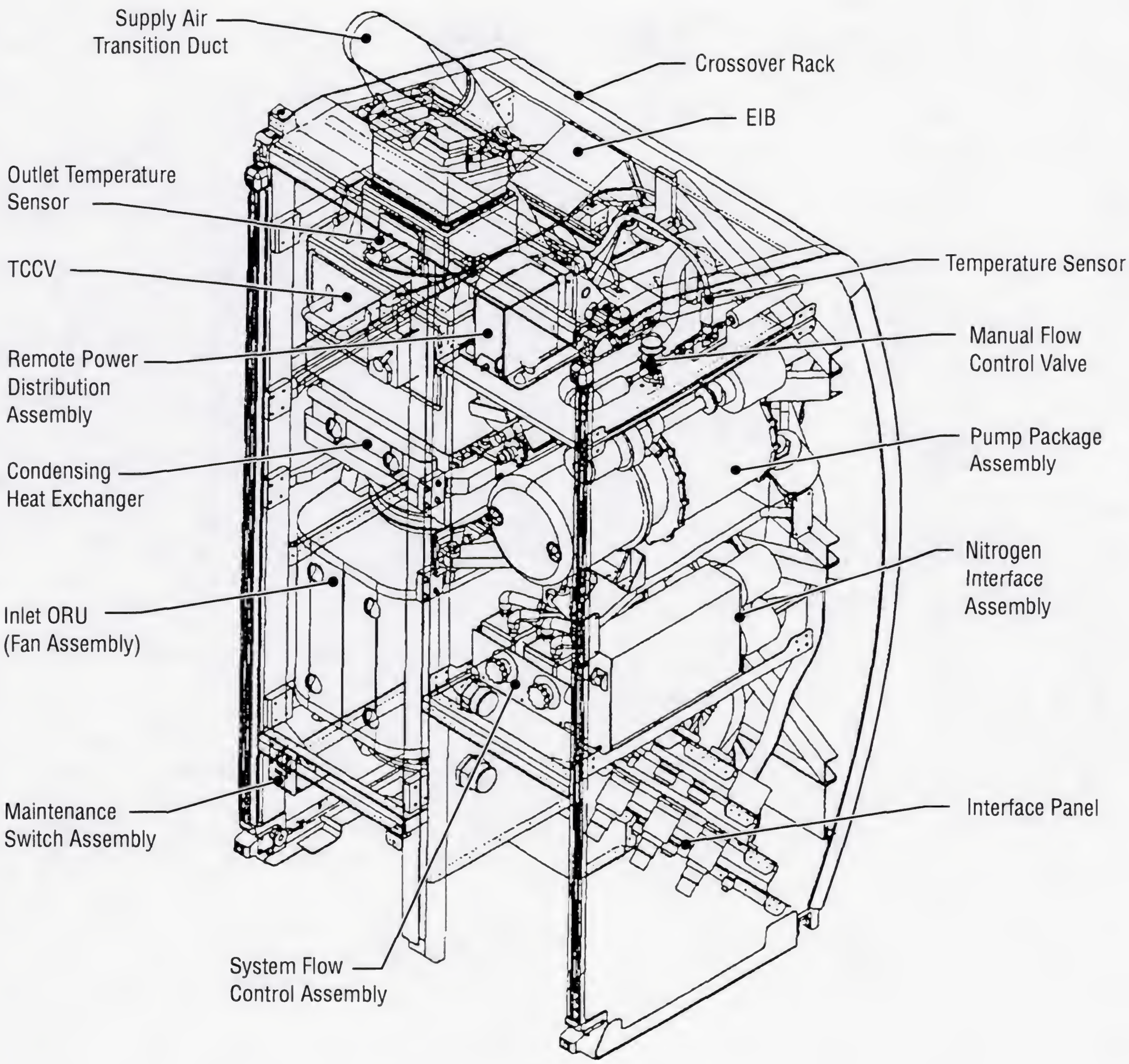


Figure 53.—THC/TCS packaging in Rack LAP6.

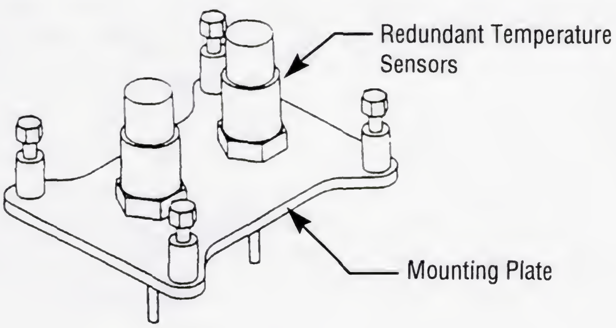


FIGURE 54.—USOS atmospheric temperature sensor.

3.2.1.2.1 CCAA Design

The CCAA is designed to be repairable by replacement of ORU's. The ORU's are described briefly in this section. For a more detailed description, see D683–14719–1–7, Revision New.

Inlet ORU—The Inlet ORU, shown in figure 55, consists of the fan group with a fan assembly, a fan ΔP sensor, and an acoustic enclosure.

Fan Assembly—The fan is an impeller design with axial rotation (including stator vanes and flow distributor) as shown in figure 56. It is driven by a brushless dc motor and controlled by an electronic controller that operates the

motor and provides speed and temperature information. A ΔP sensor measures the pressure rise across the fan and an acoustic enclosure contains noise generated by the fan. Mounting points are provided for use of two *ISS*-common removable ORU handles.

CCAA fan assembly characteristics are:

- Mass
  - 12.7 kg (27.9 lb)
- Power consumption
  - 410 W
- Volume
  - 0.04 m^3 (1.43 ft^3).

The controller and the ΔP sensor are mounted directly to the fan housing. The fan housing, in turn, is mounted to the structural frame on four acoustic-and-vibration-isolation mounts to limit structure-borne noise and vibration. The acoustic enclosure is mounted to the frame on elastomeric pads and surrounds the fan housing to block case-radiated noise. The assembly inlet and outlet ducts are also attached to the frame.

Within the enclosure, the air is directed to and from the inlet and outlet of the fan housing with flexible elastomeric couplings that act to isolate fan housing vibration while preventing air recirculation from the fan outlet back to the fan inlet. The assembly electrical connections for power in, signals out, and ΔP sensor input/output are mounted to the inlet end of the acoustic enclosure.

The structural frame extends through the acoustical enclosure to provide the four structural mounting points for the assembly. The structural interface consists of four mounting pads with two captive fasteners located at each pad. One pad contains an alignment pin and it is designated as a three-force mount capable of taking loads in three directions. A second pad with no alignment pin is designated as a one-force mount. The fourth pad, which contains an alignment pin, acts as a redundant mount so that if any of the other pads fail, the assembly will still be sufficiently supported. This extra mount allows the assembly to be defined as "non-fracture critical."

Fan ΔP Sensor—A linear variable pressure transducer (LVPT), provides linear output voltage proportional to the core displacement. It is connected directly to the MDM Input/Output (I/O) card. The characteristics are:

- Mass
  - 0.3 kg (0.7 lb)
- Power consumption
  - 240 mW via MDM
- Volume
  - 0.06 L (0.002 ft^3)).
- Measurement range
  - 0 to 28 cm (11 in) H_2O with $\pm$ 0.7 percent ($\pm$ 0.213 cm (0.084 in) H_2O) accuracy
- Input voltage
  - 15 +1.8 Vdc with output of 4 to 20 mA dc current loop proportional to input pressure

HX ORU—The HX ORU consists of a CHX, temperature sensor ORU, the TCCV, and associated ducting hoses.

Condensing Heat Exchanger—As shown in figure 57, the CHX is a plate fin core design with a four-pass cross-counter flow coolant circuit (based on the Spacelab design), with 33 air and 34 coolant layers constructed of stainless steel ruffled fins. The air-side passages are coated with a hydrophilic material that promotes film wetting on the surfaces, thereby minimizing droplet formation which could cause partial flow blockage and subsequent sudden and abrupt droplet expulsion. A silver (Ag) biocide is impregnated in the hydrophilic coating to inhibit microbial growth. The device that removes the condensed water is referred to as a "slurper bar" (shown in fig. 58) because water and air are sucked into the device through a large number of small holes. The CHX has the following characteristics:

- Liquid flowrate
  - 558 kg/hr (1,230 lb/hr) (Lab, Hab)
  - 272 kg/hr (600 lb/hr) (Node 2 and AL)
- Mass
  - 20.6 kg (45.5 lb)
- Volume
  - 0.040 m^3 (1.4 ft^3)
- Material
  - Stainless steel ruffled fins
- Hydrophilic coating with biocide to minimize droplet formation and for microbial control
- 2 to 3 percent of HX air is drawn through the slurper into the water separator

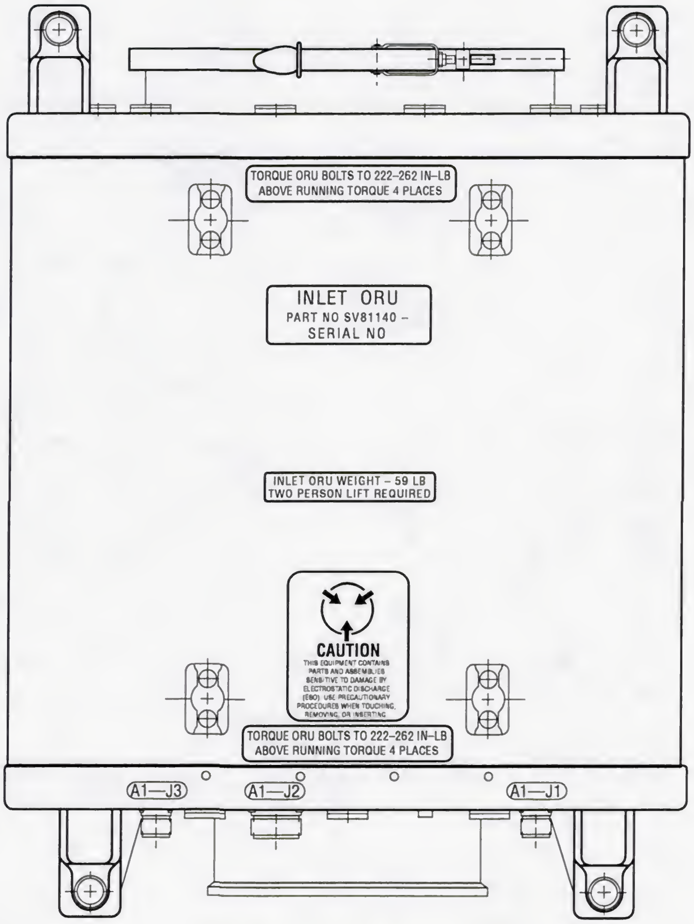


FIGURE 55.—CCAA Inlet ORU

- Effectiveness (in metric units)
  - 87 percent at 101.3 kPa and 558 kg/hr ITCS and 7,815 L/min airflow
  - 91.5 percent at 70.3 kPa and 558 kg/hr ITCS and 10,279 L/min airflow
  - 85.5 percent at 101.3 kPa and 272 kg/hr ITCS and 9,430 L/min airflow
  - 89.5 percent at 70.3 kPa and 272 kg/hr ITCS and 11,327 L/min airflow
- Effectiveness (in U.S. units)
  - 87 percent at 14.7 psia and 1,230 lb/hr ITCS and 276 cfm airflow
  - 91.5 percent at 10.2 psia and 1,230 lb/hr ITCS and 363 cfm airflow
  - 85.5 percent at 14.7 psia and 600 lb/hr ITCS and 333 cfm airflow
  - 89.5 percent at 10.2 psia and 600 lb/hr ITCS and 400 cfm airflow.

Temperature Control and Check Valve (TCCV)—Within each CCAA, the TCCV controls the amount of air that flows through or around the CHX. Depending on the amount of cooling required, the flow through the CHX will be more or less. A Proportional-Integral (PI) control scheme is used to maintain the cabin temperature at the crew selected temperature set point between 18.3 to 26.7 °C (65 and 80 °F). The maximum allowable error ("dead band") between the actual temperature and the setpoint temperature is 0.5 °C (1 °F). When the error is >0.5 °C (1 °F) the PI controller modulates the TCCV to either permit more flow through the CHX (lowering the temperature) or more flow through the bypass (raising the cabin temperature). There is also a manual override lever. For 12,716 L/min (430 cfm) airflow, the minimum by-pass flow is 850 L/min (30 cfm) and the minimum HX flow is 1,444 L/min (51 cfm). The flow split gain is limited to 413.4 L/min (14.6 cfm)/degree of valve rotation. The chassis, doors, and actuator housing are made of aluminum and the pivot shaft is made of stainless steel.

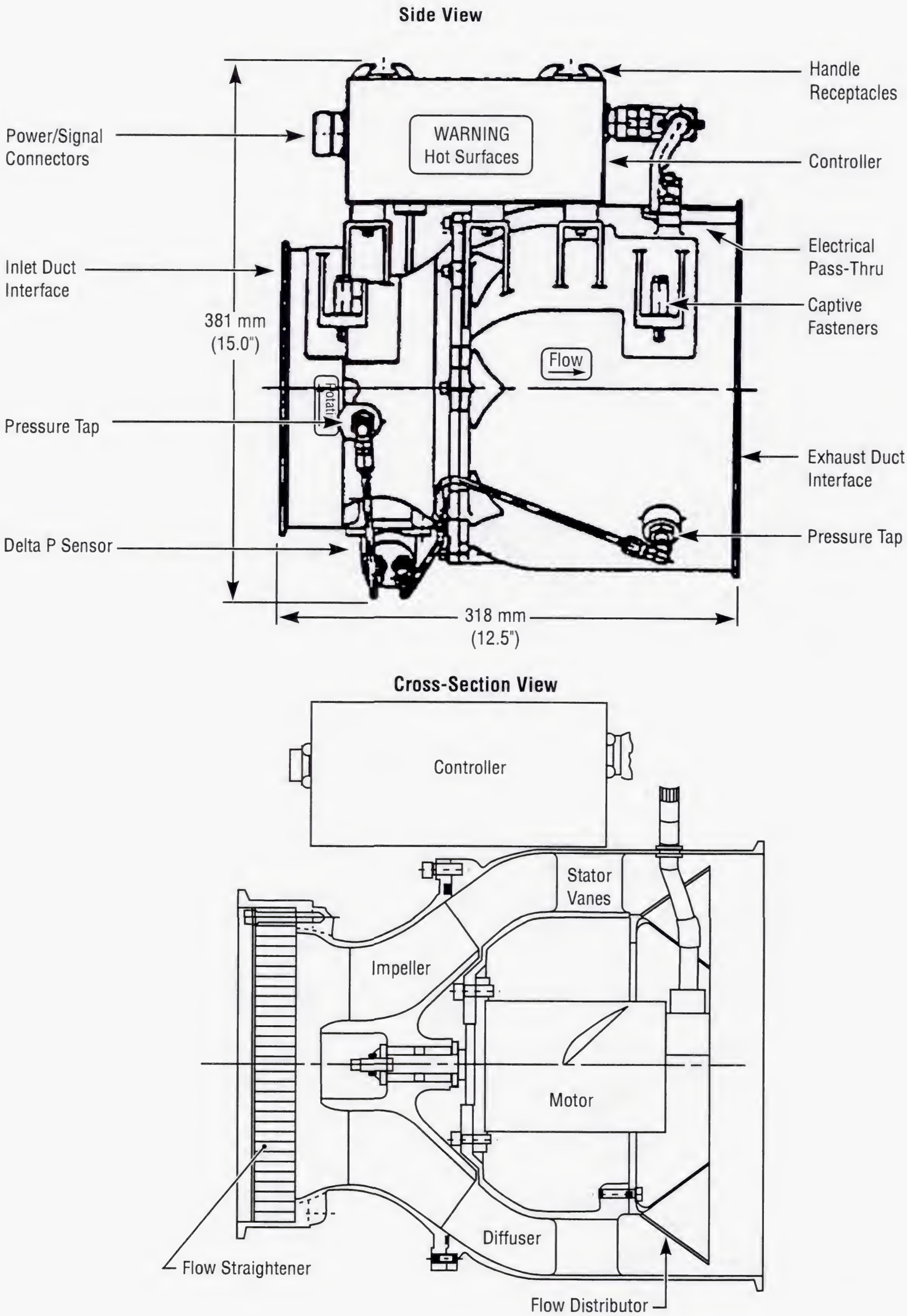


FIGURE 56.—CCAA THC fan assembly.

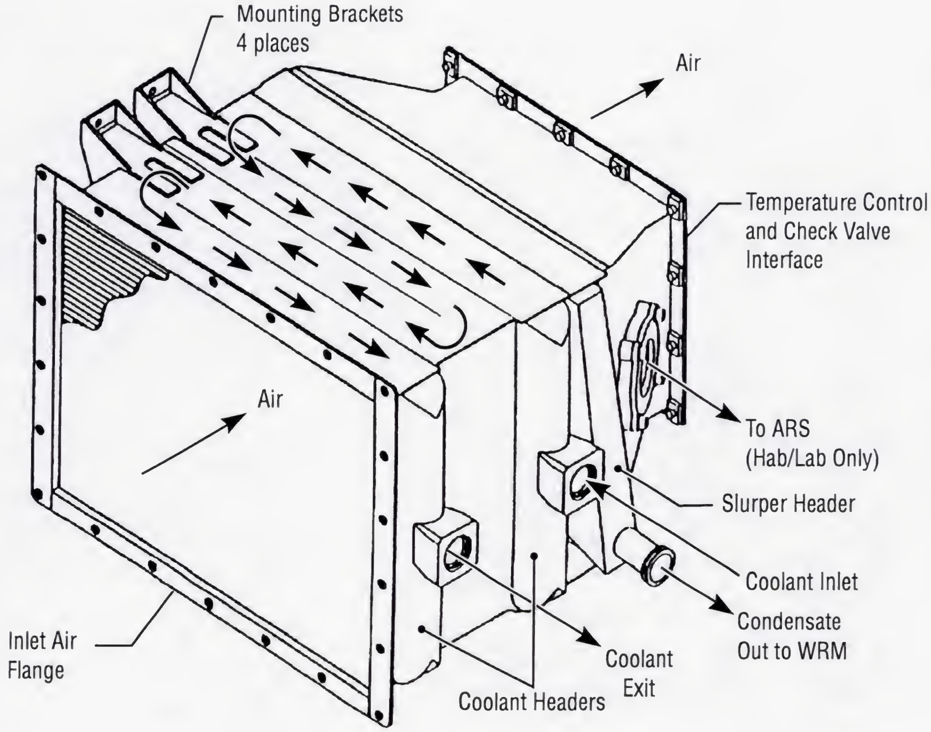


FIGURE 57.—THC CHX schematic.

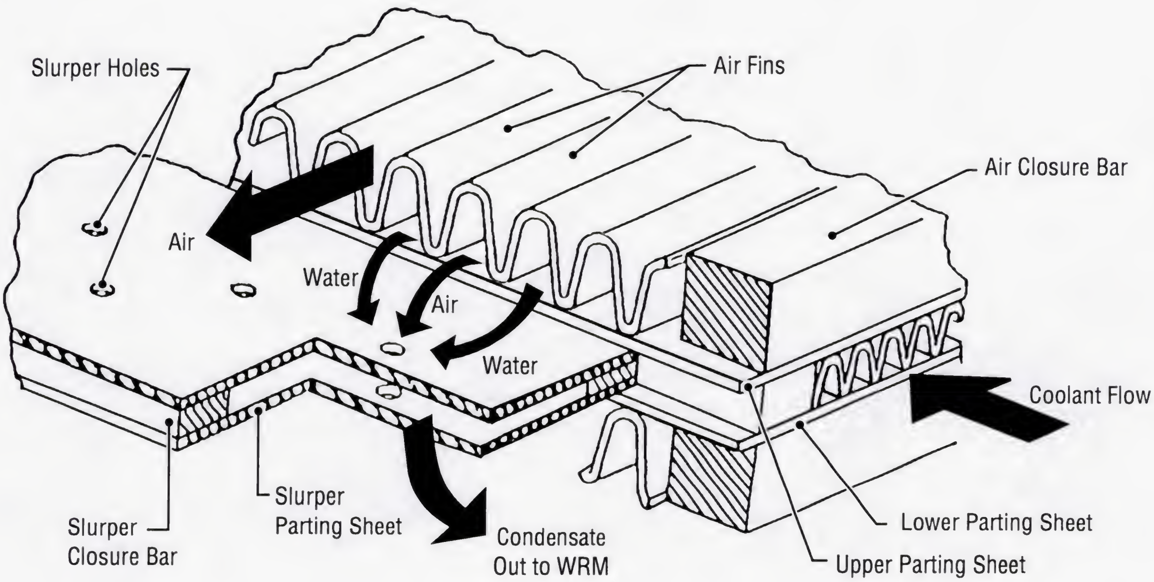


FIGURE 58.—THC CHX "slurper bar" schematic.

A schematic of the TCCV is shown in figure 59. The TCCV is held in place with six captive fasteners. An attached handle aids removal and installation of the ORU.

The TCCV is a variable air damper operated by a 120 Vdc brushless motor with manual override. It has the following characteristics:

- Mass
  - 6.3 kg (13.9 lb)
- Power consumption
  - 6.8 W static and 15.7 W dynamic
- Volume
  - 0.027 m^3 (0.95 ft^3).

Water Separator (WS) ORU—The WS ORU, shown in figure 60, consists of a WS, pressure sensor, and liquid sensor.

WS—The WS design is based on the space shuttle/ Spacelab WS but uses a 120 Vdc brush-less motor. The WS consists of a rotating drum, pitot tube, centrifugal fan, relief valve (145 kPa (21 psid) cracking pressure), solenoid valve, pressure sensor, air check valve, and speed sensor. The inlet fluid is 90 percent liquid, by volume. The outlet condensate pressure is 276 kPa (40 psig) with more than 1.45 kg/hr (3.2 lb/hr) condensate flowrate. The construction material is cast aluminum with brazed components. It has the following characteristics:

- Mass
  - 11.95 kg (26.34 lb)
- Power consumption
  - 46.36 W
- Volume
  - 0.054 m^3 (1.9 ft^3).

Pressure Sensor (for WS)—The pressure sensor is a bonded foil strain gauge type with proportional differential voltage output when the bridge is imbalanced. The pressure sensor is connected directly to the MDM I/O card. It has the following characteristics:

- Measurement range
  - 0 to 517 kPa (75 psig) with ±3 percent (±15.7 kPa) (±2.28 psig)
- Input voltage
  - 15 ±1.8 Vdc with output of 4 to 20 mA dc current loop proportional to input pressure
- Mass
  - 1.66 kg (3.66 lb)
- Power consumption
  - 240 mW via MDM
- Volume
  - 57 cm^3 (3.5 in^3).

Water Separator Liquid Sensor—The water separator liquid sensor, shown in figure 61, detects the presence of water in the air side of the separator. The sensor detects a water slug 0.89 cm (0.35 in) diameter . The time that water is present is accumulated. Its characteristics are:

- Mass
  - 0.64 kg (1.4 lb)
- Power consumption
  - 9 mW via MDM
- Volume
  - 566 cm^3 (0.02 ft^3).

Liquid Sensor ORU—The liquid sensor ORU consists of an HXLS.

Heat Exchanger Liquid Sensor (HXLS)—The HXLS, shown in figure 62, detects the presence of water on the duct wall downstream of the THC assembly. The sensor signal conditioner is connected directly to the MDM I/O card and/or electrical interface box. Its characteristics are:

- Mass
  - 0.454 kg (1.0 lb)
- Power consumption
  - 9 mW via MDM
- Volume
  - 283 cm^3 (0.01 ft^3).

EIB ORU—The EIB ORU consists of an EIB and a cooling interface.

Electrical Interface Box (EIB)—The EIB, shown in figure 63, provides signal conditioning for sensors that are incompatible with the MDM, on/off control, dual voltage solenoid valve driver, overcurrent protection, Built-In-Test (BIT) circuitry, and output status. The C&DH interfaces are:

- Passive discrete BIT command (MDM to EIB)
- Passive discrete valve command (MDM to EIB)
- Active discrete EIB enable command (MDM to EIB)
- Passive discrete EIB status (EIB to MDM)

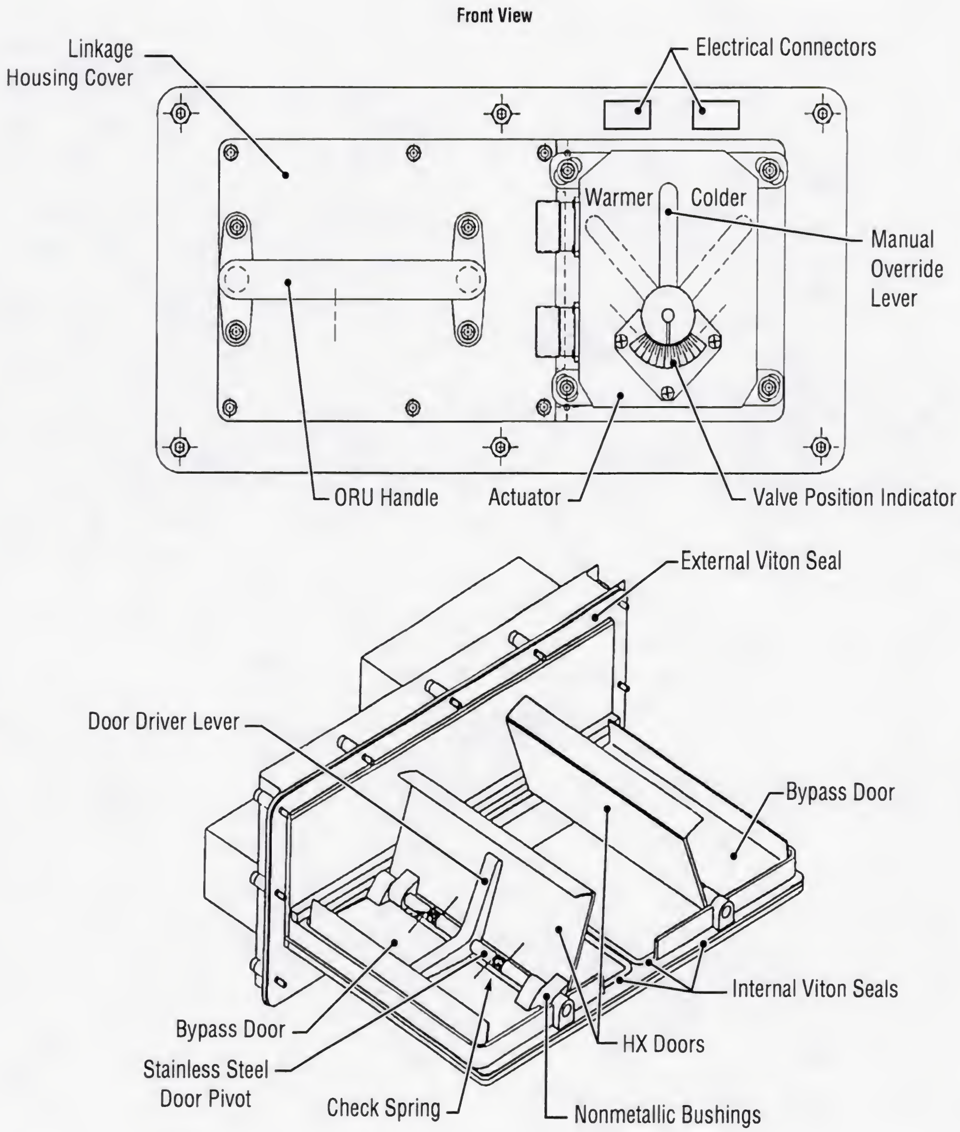


FIGURE 59.—THC TCCV.

- Active discrete HX liquid sensor (MDM to EIB)
- Analog balanced differential WS liquid sensor (EIB to MDM)

The EIB characteristics are:

- Components
  - 1 motherboard, 4 daughter boards, 1 filter, circular I/O connectors
- Material
  - Anodized aluminum
- Mass
  - 5.7 kg (12.5 lb)
- Power consumption
  - 6.5 W
- Volume
  - 0.0097 m^3 (590 in^3).

The EIB is attached by four captive fasteners and has a detachable handle to aid removal and installation.

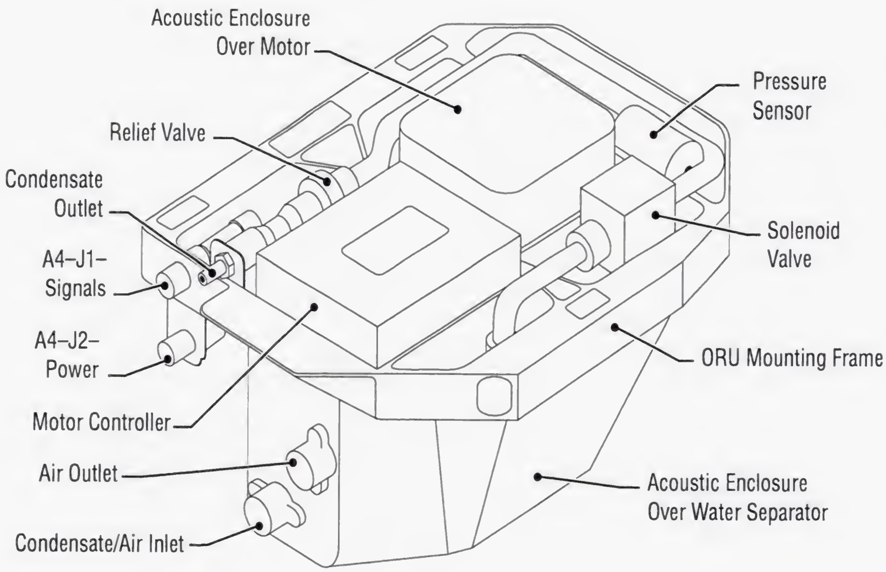


FIGURE 60.—THC CCAA water separator.

Temperature Sensor ORU—The Inlet and Outlet Temperature Sensor ORU's are identical. The sensors are platinum RTD's that are connected directly to the MDM I/O card. The characteristics are:

- Measurement range
  - 4.44 to 32.2 °C (40 to 90 °F) with ±1 percent ±0.25 °C (±0.5 °F) full-scale accuracy
- Mass
  - 270 g (0.59 lb)
- Volume
  - 0.0011 m^3 (67 in^3).

3.2.1.2.2 CCAA Operation

The CCAA process is shown schematically in figure 64. Filtered air is drawn from the cabin by the Inlet ORU. The Inlet ORU provides the necessary head rise to move air through the CCAA as well as the cabin and system ducting. The cabin temperature is controlled to a crew-selectable set point temperature by positioning the TCCV ORU via a PI control scheme based on the difference between the Inlet Temperature ORU signal and the cabin set point. The position of the TCCV determines the flow split between the CHX and the bypass ducts. Heat and moisture are removed from the portion of the airflow directed through the CHX. The heat removed from the air is transferred to the coolant water loop. Bypass air and CHX airflow streams are then mixed downstream of the TCCV and cool, dehumidified air is returned to the cabin through the outlet housing. The condensed moisture, along with some air, is drawn from the CHX by the Water Separator ORU where condensate and air are separated. The condensate is delivered to the condensate bus while the air is returned to the outlet air stream. The humidity condensate water is delivered to the wastewater bus at a rate up to 1.45 kg (3.2 lb) per hour at a pressure of up to 55 kPa (8 psig). A Liquid Sensor ORU indicates excessive condensate carryover by monitoring the condition of the air in the ducting downstream of the CCAA. In addition to air being delivered to the cabin, a separate port upstream of the TCCV ORU allows withdrawal of high relative humidity air.

CCAA's are located in four places (Hab, Lab, Node 2, and AL); however, the performance requirements are not the same in all applications. The performance of the CCAA's is tailored for the application by the controlling software. The applications are identified as Type 1 (Hab and Lab) and Type 2 (Node 2 and AL). The CCAA operating conditions (Type A normal condition and Type B low-pressure condition) are described in table 22 for the Type 1 and Type 2 applications. The effective average velocity in the habitat aisleway is 4.6 to 12.2 m/min (15 to 40 fpm), with a minimum average of 3 m/min (10 fpm) when supporting high heat loads in "parasitic" pressurized volumes (i.e., Node 1 with or without the Cupola and the MPLM). Two-thirds of the velocities are in the 4.6 to 12.2 m/min (15 to 40 fpm) range, with lower and upper limits of 2 and 61 m/min (7 and 200 fpm), respectively (for localized flow near a diffuser).

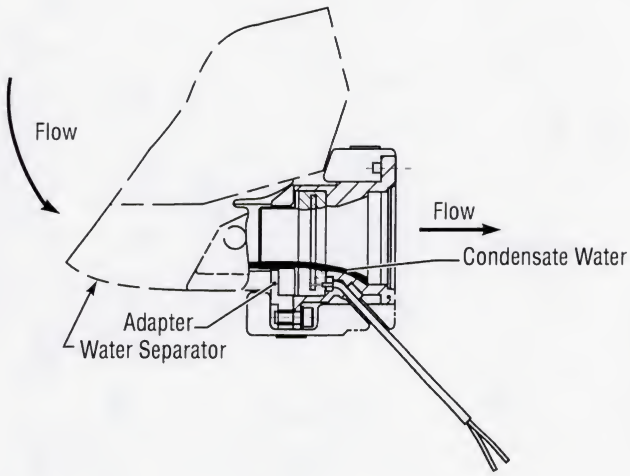


FIGURE 61.—THC CCAA WS liquid sensor.

The CCAA is operated via six commands (from MDM's in racks LA–1 and LA–2) to the CCAA internal Computer Software Configuration Item (CSCI) directing the CCAA to a final operating configuration or to perform a specified operation. The operational commands can be overridden via the MDM's to modify the operating parameters per user requests. There are eight states internal to the CCAA CSCI, as shown in figure 65.

Operation of the CCAA involves the following commands:

- Initialize
  - Resets faults/overrides, runs active BIT, places in Off state.
- Operate
  - Goes to Startup state and goes to On state when startup is complete.
- Standby
  - Goes to Startup state and waits for Operate command (with WS on).
- BIT Execution
  - Goes to Test state, runs BIT, and goes to Off state.
- Shutdown
  - Goes to Dryout state, proceeds to Drain state, ends in Off.
- Stop
  - Goes directly to Off.

3.2.1.2.3 CCAA Performance

Heat is removed via the water-cooled ITCS to maintain a crew-selectable cabin temperature between 18.3 to 27 °C (65 and 80 °F). The stabilized temperature within the cabin is within ±1 °C (2 °F) of the selected temperature. The Lab and Hab THC can remove 3.5 kW (including 1.0 kW latent heat) from the Lab atmosphere. (The AL and Node 2 THC have less capability due to a lower coolant flowrate. Node 1 and the Cupola do not have THC units and the allowable temperature range is 18.3 to 29.4 °C (65 to 85 °F).) The cabin RH is maintained within the 25 to 75 percent range. The dew-point temperature is in the 4.4 to 15.6 °C (40 to 60 °F) range. Data and commands are transferred via a command and control processor and 120 V dc power is provided from the secondary electrical power supply.

3.2.1.3 Avionics Air Assembly (AAA)

The AAA, shown in figure 66, provides cooling and atmospheric flow for FDS operation for rack-mounted equipment. The primary components of the AAA are a variable speed fan, HX, smoke detector, and a firmware controller. A combination of mufflers at the inlet and outlet provide high- and low-frequency airborne noise control. An acoustic enclosure provides case-radiated noise protection.

Inlet air as warm as 41 °C (105 °F) flows through mufflers before entering the inlet duct where a smoke detector is located upstream of the fan. The fan provides sufficient pressure rise to allow a 51 mm (2 in) H_2O pressure drop in the payload rack, as well as compensate for losses in the AAA itself. As the air leaves the fan it expands through a transition section before entering the HX, where it is cooled to a maximum temperature of 22.2 °C (72 °F) before it is discharged through the outlet muffler into the rack.

The AAA fan is a compact, highly integrated assembly consisting of a fan, motor, sensors, control electronics, and mounting structure. The fan is driven at 18,000 rpm by a brushless dc motor built into the fan housing. Sensors for monitoring flowrate and temperature are mounted in the airflow path. The maximum fan power consumption is 145 W at 56.6 L/sec (120 cfm). The air-water HX is a cross-counterflow plate-fin design with integral water headers. It is highly compact and maintains effectiveness over an air flow range of 18.9 to 56.6 L/sec (40 to 120 scfm) and a coolant flow range of 45.4 to 81.7 kg/hr (100 to 180 pph). The maximum heat rejection is 1,200 W at 101.3 kPa (14.7 psia).

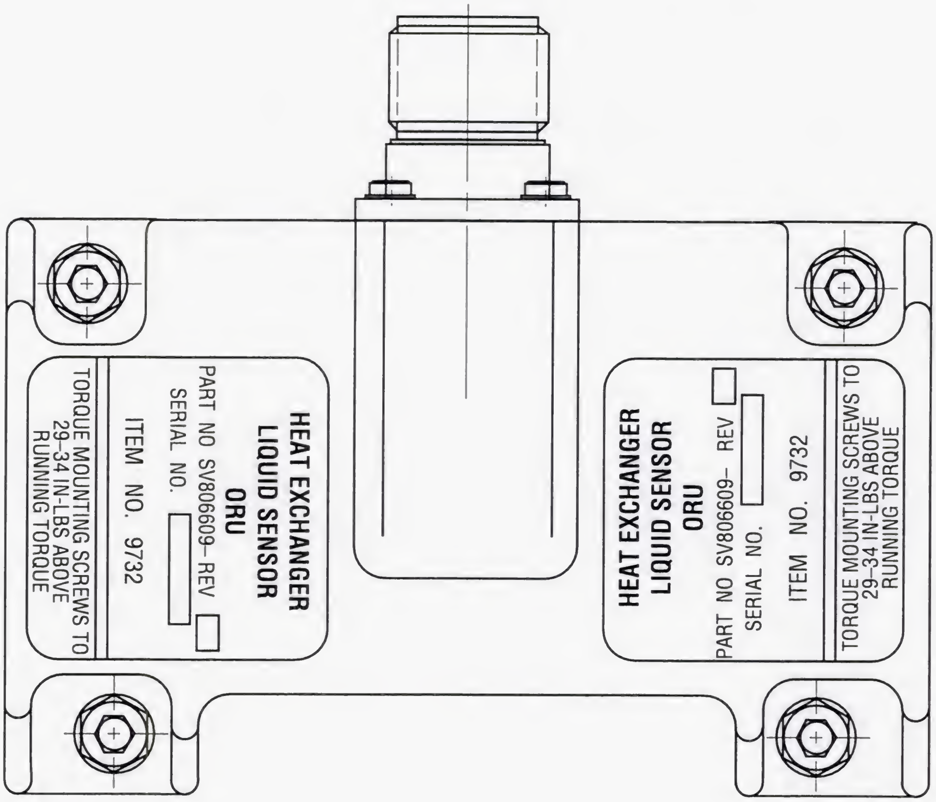
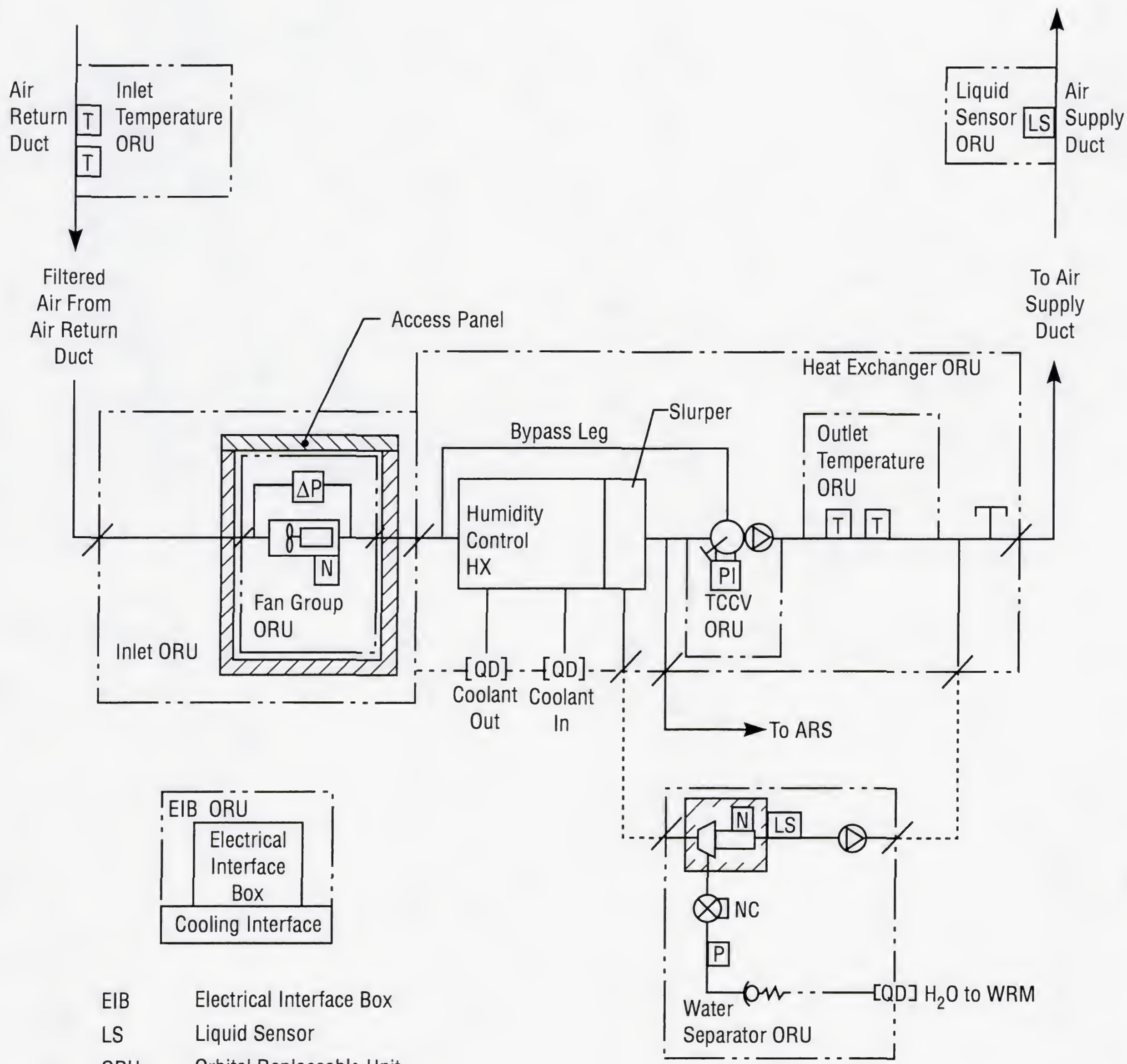


FIGURE 62.—THC CCAA HX liquid sensor.

FIGURE 63.—THC CCAA EIB.



EIB	Electrical Interface Box
LS	Liquid Sensor
ORU	Orbital Replaceable Unit
ΔP	Differential Pressure Sensor
PI	Proportional-Integral Controller
T	Temperature Sensor
(check valve symbol)	Check Valve
TCCV	Temperature Control and Check Valve
P	Pressure Sensor
NC	Normally Closed Solenoid Valve
N	Speed Sensor
QD	Quick Disconnect

Figure 64.—CCAA process schematic.

TABLE 22.—*CCAA operating conditions.*

Interface		Units	Operating Condition Type A (normal)	Operating Condition Type B (low pressure)
• Return Duct/Temp Sensor ORU Interface				
Air Temperature		°C (°F)	17.2–27.8 (63–82)	17.2–27.8 (63–82)
Air Absolute Pressure		kPa (psia)	99.2–102.7 (14.4–14.9)	61.3–73.0 (8.9–10.6)
Air Dewpoint Temperature		°C (°F)	4.4–14.4 (40–58)	4.4–14.4 (40–58)
Air Relative Humidity		%	25–70	25–70
Air Velocity		m/min (ft/min)	4.6–9.1 (15–30)	4.6–9.1 (15–30)
• Return Duct/Assembly Interface				
Air Temperature	Type 1*	°C (°F)	15.6–28.3 (60–83)	15.6–28.3 (60–83)
	Type 2	°C (°F)	17.2–27.8 (63–82)	17.2–27.8 (63–82)
Air Absolute Pressure		kPa (psia)	99.2–102.7 (14.4–14.9)	61.3–73.0 (8.9–10.6)
Air Dewpoint Temp.	Type 1	°C (°F)	3.3–15.6 (38–60)	3.3–15.6 (38–60)
	Type 2	°C (°F)	4.4–14.4 (40–58)	4.4–14.4 (40–58)
Air Relative Humidity	Type 1	%	20–75	20–75
	Type 2	%	25–70	25–70
• Supply Duct/Liquid Sensor ORU Interface				
Air Relative Humidity		%	20–100	20–100
Air Dewpoint		°C (°F)	3.3–15.5 (38–60)	3.3–15.5 (38–60)
Airflow Velocity		m/sec (ft/sec)	3.5–6.4 (11.5–21.0)	3.5–6.4 (11.5–21.0)
Air Temperature		°C (°F)	6.7–28.3 (44–83)	6.7–28.3 (44–83)
Carryover Water Conductivity		μmhos/cm	20–150	20–150
• ARS Duct Interface				
Air Flowrate	Type 1	L/sec (acfm)	9.4 max (20 max)	9.4 max (20 max)
• Coolant Water Supply Interface				
Supply				
Water Temperature		°C (°F)	3.3–5.6 (38–42)	3.3–5.6 (38–42)
Water Flowrate	Type 1	kg/hr (lb/hr)	529–588 (1,165–1,295)	529–588 (1,165–1,295)
	Type 2	kg/hr (lb/hr)	272 (600 min)	272 (600 min)
Water Absolute Pressure (MOP)		kPa (psia)	689 (100 max)	689 (100 max)
Return		N/A	Coolant water which exits the CCAA CHX	
• Condensate Bus Interface				
Condensate Gauge Pressure (referenced to ambient)		kPa (psig)	0.0–55.1 (0–8)	0.0–55.1 (0–8)
• Ambient Air Interface				
Air/Surrounding Surface Temp.		°C (°F)	21.1–42.3 (70–109)	21.1–42.3 (70–109)
Air Absolute Pressure		kPa (psia)	99.9–102.7 (14.5–14.9)	62.0–73.0 (9.0–10.6)
Air Dewpoint Temperature		°C (°F)	4.4–14.4 (40–58)	4.4–14.4 (40–58)
Air Relative Humidity		%	10–70	10–70
Air Velocity		m/min (ft/min)	0 (0)	0 (0)
Air Oxygen Concentration		%	19.0–23.1	24.1–28.5

*Type 1–Hab and Lab
Type 2–Node 2 and AL

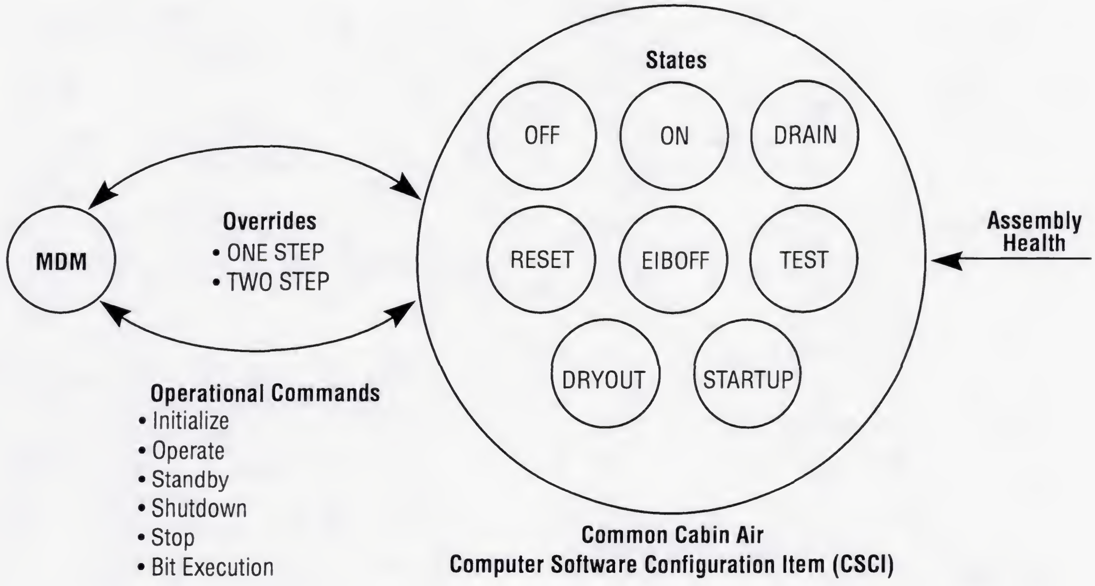
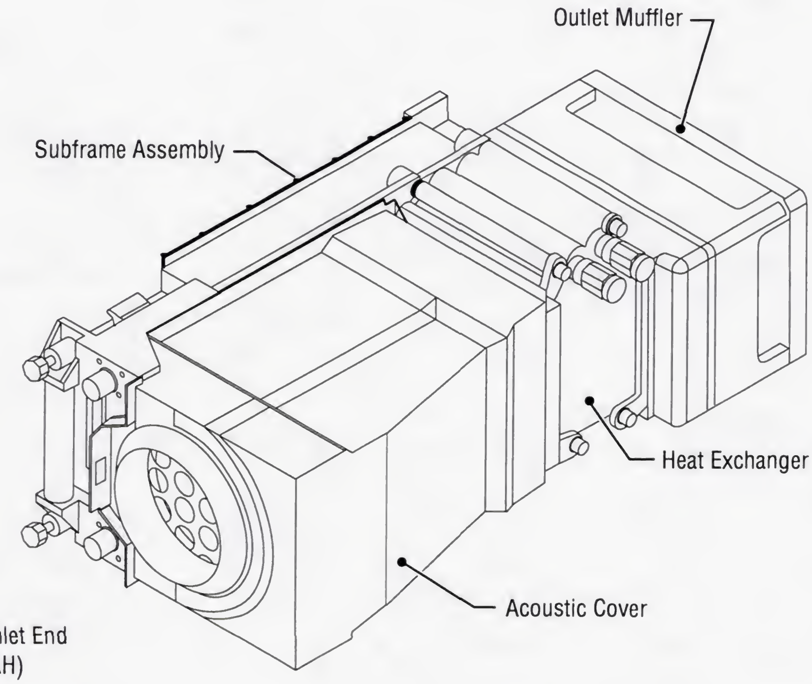


FIGURE 65.—CCAA commands/overrides/states.



Components:

- Inlet and Outlet Mufflers
- Fan With Motor Controller
- Heat Exchanger

Features:

- Single ORU Packaging
- Axial Air Inlet, 4 in dia. V-Band clamp
- Radial Air Outlet, 4 Port Discharge
- Captive Fasteners and Electrical I/F at Inlet End
- Common Coolant Fittings (3/8 in GAMAH)
- Built-in On-Orbit Grasp Handle

Avionics Air Assembly

FIGURE 66.—USOS AAA schematic.

3.2.2 Control Atmospheric Moisture

For the USOS, atmospheric temperature control and humidity control are performed by the same subsystem, described in section 3.2.1.

3.2.2.1 Monitor Humidity

Atmospheric moisture is not monitored.

3.2.2.2 Remove Atmospheric Moisture

The CHX removes moisture via the slurper bar device (see section 3.2.1.2, describing the CHX, and fig. 58). A water separator provides the necessary suction at the CHX outlet to remove the condensate and a small portion of air. The separator, shown in fig. 67, consists of a rotating drum, pitot tube, centrifugal fan, relief valve, solenoid valve, pressure sensor, air check valve, and speed sensor. The air/water mixture (90 percent liquid, by volume) is drawn into the central inlet. As the mixture is driven radially outward, the water is separated from the air by centrifugal action. A stationary pitot tube is immersed in the rotating ring of water. The rotation speed forces the water into the pitot tube, through the solenoid valve and relief valve, and into the liquid condensate line. The air check valve prevents backflow when the separator is not operating. The relief valve prevents condensate backflow and regulates upstream pressure to minimize air inclusion. Back-pressure ensures that the water level in the drum is always sufficient to cover the pitot inlet, thereby preventing air inclusion in the condensate line. Air is returned to the cabin. The water separator characteristics are:

- Mass
  - 11.9 kg (26.3 lb)
- Power consumption
  - 46.4 W.
- Volume
  - 0.05 m^3 (1.9 ft^3)

3.2.2.3 Dispose of Removed Moisture

Condensate water is collected and piped to a storage tank. The storage tanks are metal bellow tanks made of Inconel™. From 0 to 5 percent of the condensate water is entrained air. The condensate is then processed in the water processor for potable and hygiene water use.

3.2.3 Control Airborne Particulate Contaminants

Airborne particulate contaminants are removed by filtering the air before it enters the ventilation system ducting.

3.2.3.1 Remove Airborne Particulate Contaminants

Particulates and microorganisms are removed by HEPA filters that remove 99.97 percent of particles 0.3 micron or larger in diameter. These filters are made of a "paper" of borosilicate glass fibers folded and fastened in a housing which allows easy replacement of the filters, and an ethyltetrafloroethylene (ETFE) pre-filter screen to exclude free liquid, as shown in figure 68. These filters are considered to be part of the THC subsystem.

3.2.3.2 Dispose of Airborne Particulate Contaminants

The filters are checked and cleaned by vacuuming every 90 days if necessary, and they are replaced once per year. To replace a filter, the atmospheric flow in the ventilation duct is first shut off by manually closing the duct damper to preclude particulates from being drawn into the ventilation system. There is a separate damper in each leg of the ventilation ducting, as shown in figure 69. The assembly is designed to provide one-handed operation with a friction hinged door to stay in any position to facilitate routine element replacement. A simple pull-strap aids removal of the filter from the housing assembly. Spring clips and installation keys provide ease of filter element positioning and prevent incorrect installation. A perforated outlet prevents debris from entering the return duct during element replacement. The inlet grate and latch are capable of supporting crew "push off."

3.2.4 Control Airborne Microorganisms

Airborne microorganisms are also removed by the HEPA filters used to remove airborne particulates.

3.2.4.1 Remove Airborne Microorganisms

Microorganisms are removed to maintain a maximum daily average concentration of 1,000 CFU/m^3 (see section 3.2.3).

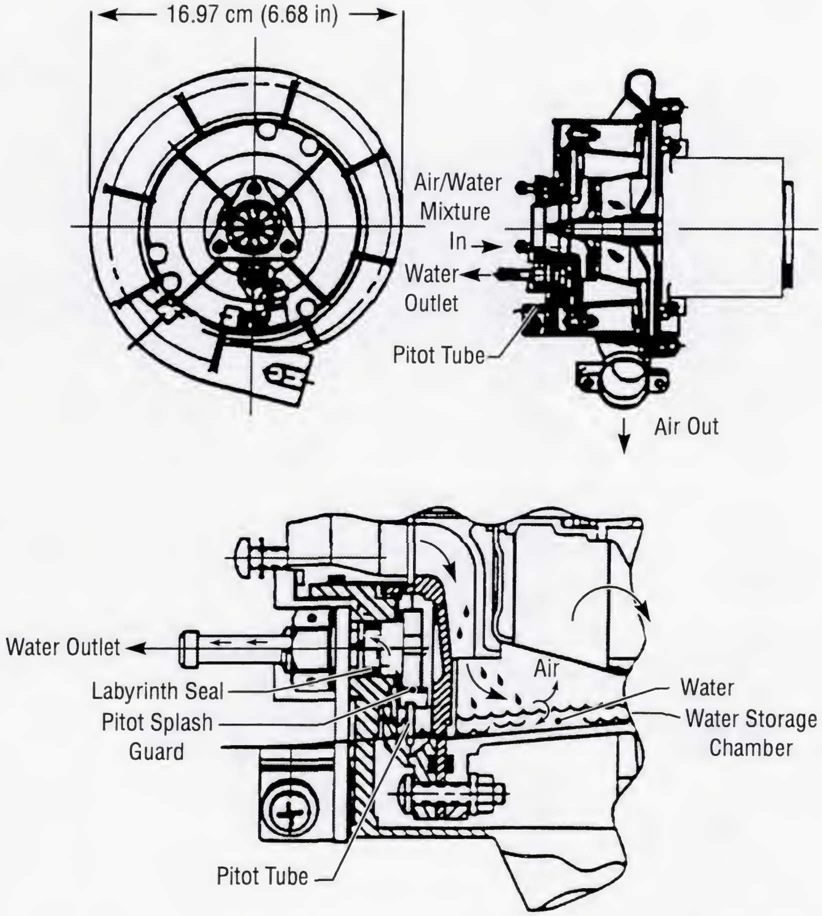


FIGURE 67.—THC water separator.

3.2.4.2 Dispose of Airborne Microorganisms

Microorganisms are disposed of by replacing the old HEPA filters with new ones and disposing of the old filters as trash (see section 3.2.3).

3.2.5 Circulate Atmosphere: Intramodule

The CCAA, described in section 3.2.1, also circulates atmosphere within a module.

Cabin Air Distribution—In the Lab, two CCAA's are connected to a distribution system that draws air from the cabin and supplies conditioned air to the cabin. Normally, only one CCAA operates at a time so "cross-over" ducts connect the CCAA's, as shown in figure 69. In the Hab, Node 2, and the AL, there is one CCAA each, connected to the ducts in each module.

The AAA removes heat from the atmosphere in the powered racks in the Lab. The thermal energy is transferred to the moderate-temperature ITCS. Data and commands are transferred via an MDM and 120 Vdc power is provided from an RPCM.

3.2.6 Circulate Atmosphere: Intermodule

IMV ensures air circulation throughout the *ISS* to provide good distribution of O_2, aid in removal of CO_2 and trace contaminants, and help to maintain appropriate temperature and RH. IMV hardware consists of two ORU's and other hardware such as ducting (which is not intended to be replaced). To connect the IMV ducting in adjacent modules, hard ducts (or "jumpers") are connected through the vestibules. These jumpers are connected with V-band clamps to the fixed adapters at the vestibule interfaces. The jumpers are about 12 cm (4.7 in) in diameter and about 0.61 m (2 ft) in length. They are lined with an acoustic damping material (solimide foam) with an additional lining of stainless steel felt. The IMV ORU's are:

Intermodule Ventilation Fan Assembly—The IMV fan (shown in fig. 70) provides for ventilation between

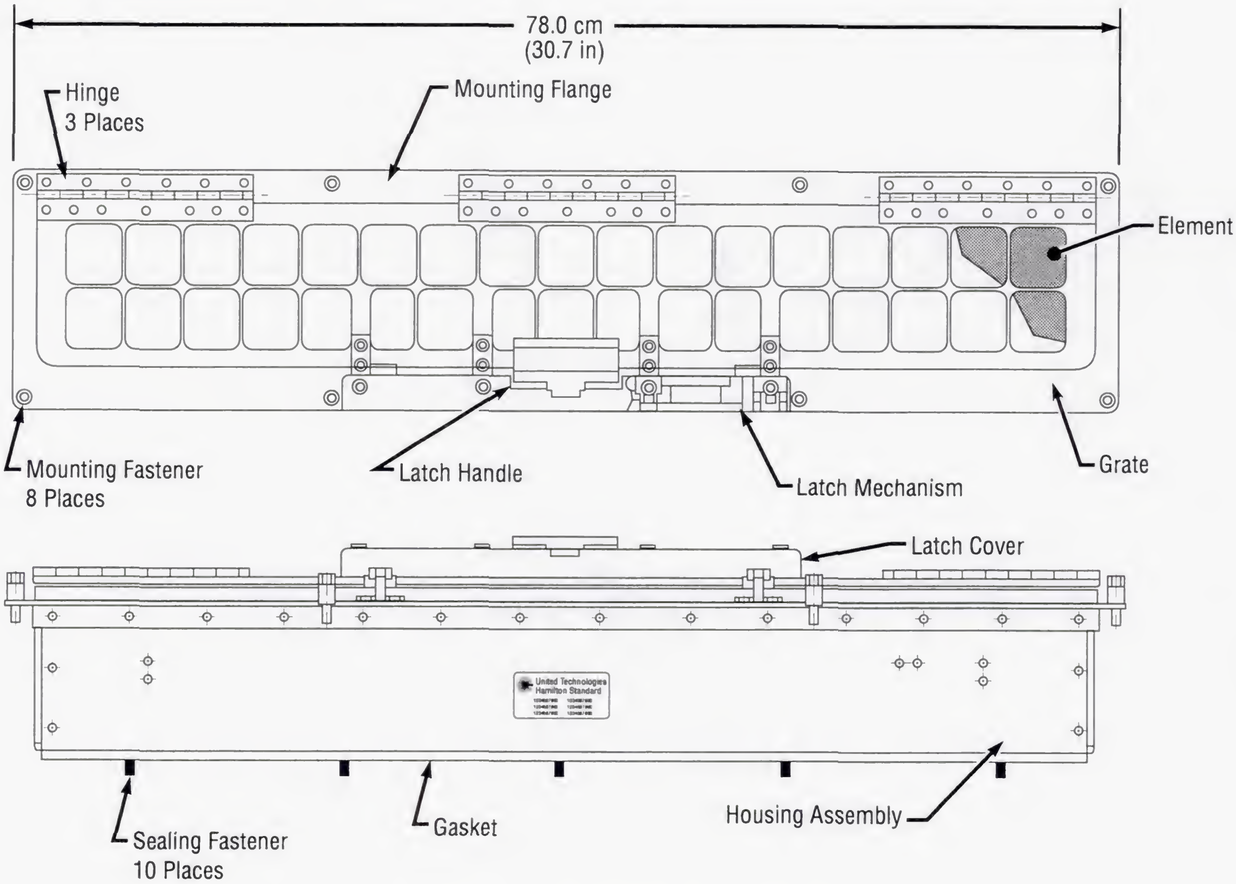


FIGURE 68.—THC HEPA filter assembly.

adjacent modules. Data and commands are transferred via an MDM and 120 Vdc power is provided from an RPCM. The rate of flow between adjacent modules is in the range 3,823 to 4,106 L/min (135 to 145 cfm). The fan is powered by a 120 Vdc brushless motor with a speed sensor. The inlet flow is protected by a honeycomb airflow straightener. IMV fan characteristics include:

- Air flowrate
  - 3,964 L/min (140 cfm) to cabin
- ΔP
  - 2.54 cm (1.0 in) water column
- Power (120 Vdc)
  - 55 W continuous
- Mass
  - 4.7 kg (10.5 lb).

Intermodule Ventilation Valve Assembly—The IMV valve (shown in fig. 71) provides the capability to isolate the atmosphere from adjacent modules when the hatches are closed. The IMV valve thus allows or prevents atmosphere exchange between adjacent modules. Data and commands are transferred via an MDM and 120 Vdc power is provided from an RPCM. The valve is an electric motor driven butterfly valve (with manual override capability), and includes an electrical motor actuator with a planetary gear drive, and spur and face gear assembly. The valve actuates when power is applied, and Magnetic Position Indicators (MPI) signal the motor controller and MDM to remove power at the end of a stroke. Electronic position sensors detect the valve end of a stroke. A high gear ratio keeps the valve in the last commanded position.

The IMV valve has the following characteristics:

- Dimensions
  - 164 by 159 by 319 mm (6.5 by 6.3 by 12.6 in)
- Mass
  - 5.34 kg (11.75 lb)

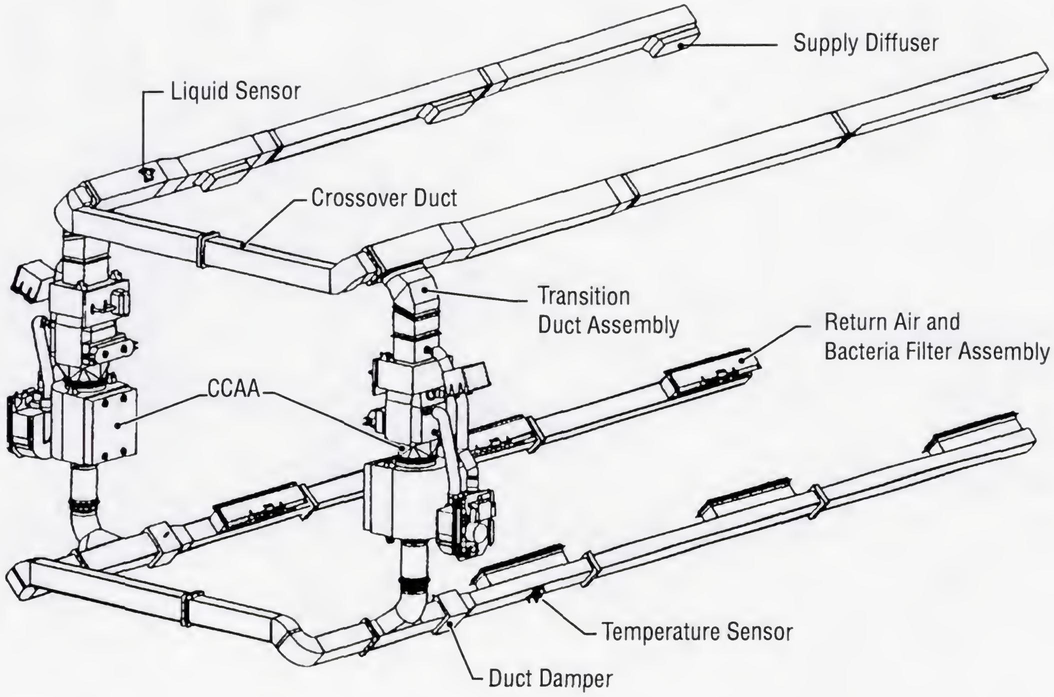


FIGURE 69.—IMV hardware.

- Air flowrate
  - 286 kg/hr at 101.3 kPa and 0.48 kPa ΔP (629 lb/hr at 14.7 psia and 0.07 psid)
- Temperature
  - Non-operating temperature range: – 95 to 71 °C (–40 to 160 °F)
  - On-orbit non-operating temperature range: –95 to 32 °C (–40 to 90 °F)
  - On-orbit operating temperature range: 1.7 to 32 °C (35 to 90 °F)
- Pressure
  - Normal operating pressure: 101.3 kPa (14.7 psia)
  - Proof pressure: 165.4 kPa (24 psid) at 23.8 °C (75 °F)
  - Burst pressure: 237.7 kPa (34.5 psid) at 23.8 °C (75 °F)
- Leakage
  - Case leakage: 0.066 scc/hr at 101.3 kPa (14.7 psid) and 23.8 °C (75 °F)
  - Port leakage: 72 scc/hr at 101.3 kPa (14.7 psid) and 23.8 °C (75 °F)
- Power consumption
  - 120 Vdc motor, 15 Vdc valve controller and sensor
  - Peak: 190 W (when the valve is activated, the average power consumption is much lower)
  - Standby: 0.15 W
  - Enabled: 6 W (maximum)
  - Operating: 20 W (maximum)
- Operating time
  - Cycle from open to closed in 30 sec maximum
- Operating cycles
  - Design life: 3,750 cycles
  - Actual operating life: More than 10 times the design life.

The IMV valve can also be operated manually using the manual override handle shown in figure 72. The override handle is engaged during normal operation for visual indication of the valve position. When the manual override is used, it disengages the motor-driven gear, providing the ability to operate the valve. Releasing and stowing the handle re-engages the motor planetary and spur gear assemblies. The actuator has mechanical stops at the open and closed positions.

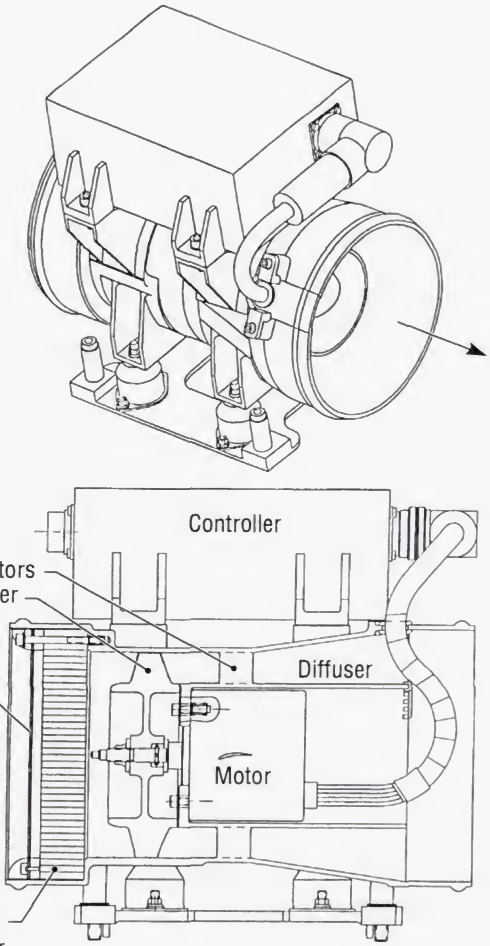


FIGURE 70.—IMV fan assembly (D683–15005–1, rev. A)

The IMV valve override handle has the following characteristics:

- Dimensions:
  - Handle assembly
    - stowed 165 by 165 by 178 mm (6.5 by 6.5 by 7.0 in)
    - deployed 236 by 305 by 279 mm (9.3 by 12 by 11 in)
  - Cable assembly—13 mm (0.5 in) diameter by 0.9 m (36 in) length
- Mass
  - 1.6 kg (3.5 lb)
- Nominal operation time
  - <5 sec
- Force to open/close
  - 89 N (20 lb).

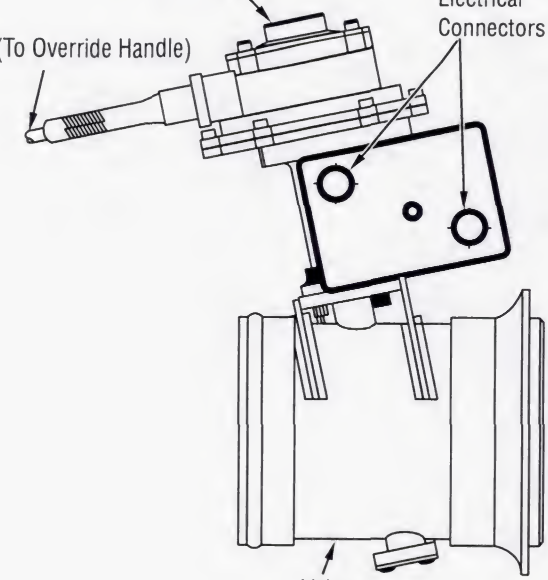


FIGURE 71.—IMV valve.

3.3 Atmosphere Revitalization (AR)

The AR subsystem removes CO_2 and potentially harmful trace gases metabolically generated by the crew and offgassed from equipment and other materials. The AR subsystem also monitors the atmosphere for the major constituents (O_2, N_2, CO_2, H_2, CH_4, and H_2O). After the Hab is installed, O_2 generation is also part of AR.

The AR subsystem interfaces are shown in figure 73. As shown in figure 74, the major components of the AR subsystem are the:

- CDRA
- OGA in the Hab
- TCCS
- MCA
- SDS in the Lab, Hab, AL, Nodes 1 and 2, the Centrifuge, and the international modules (JEM, APM, MPLM)

The locations of the AR components in the USOS are shown in figures 75 through 81. The AR rack packaging is shown in figure 82 and the AR Rack Assembly Connections are shown in figure 83.

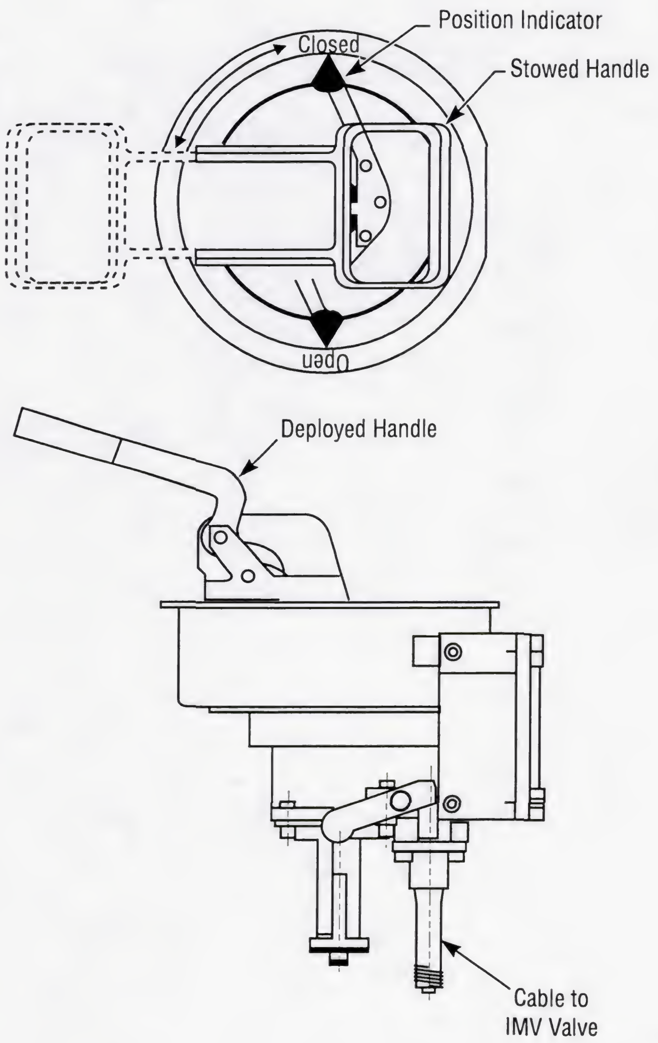


FIGURE 72.—IMV valve manual override operation.

3.3.1 Control Carbon Dioxide

The CO_2 levels are monitored and maintained within the design specifications with a CO_2 monitor and a CO_2 removal assembly.

3.3.1.1 Monitor CO_2

The CO_2 level is monitored by the MCA (see section 3.3.2).

3.3.1.2 Remove CO_2

CO_2 is removed from the habitat atmosphere by a 4BMS CDRA. Excess CO_2 is vented overboard, until a CO_2 reduction assembly is activated. (The CO_2 reduction assembly is installed after the initial *ISS* construction is completed.)

3.3.1.2.1 4BMS Design

The 4BMS removes CO_2 from the Habitat atmosphere by adsorption on Zeolite 5A molecular sieve material. As shown in figure 84, there are two canisters (or "beds") of Zeolite 5A to allow one to be regenerated, by desorption of the CO_2 while the other is adsorbing CO_2, thereby providing continuous operation. Because water is more readily adsorbed than CO_2, water vapor must first be removed. The water is adsorbed on beds of Zeolite 13X and Silica Gel (Si gel). The main features of the technology are:

- Continuous removal of CO_2 by alternating between two CO_2 sorbent beds
- Thermal/vacuum swing regeneration of the CO_2 sorbent beds
- Recovery of water vapor and atmosphere
- Open loop operation (CO_2 is vented to space vacuum)
- Removes the CO_2 generated by four people plus biological specimens
- Day/night orbital cyclic operation of sorbent bed heaters for night-side power savings
- Receives process air from either active THC unit in the Lab
- No expendables.

Water is removed from the atmospheric stream by two methods. First, the inlet duct to the 4BMS is attached downstream of the CHX in the THCS. Thus, water is removed by condensation in the THCS CHX. This also raises the RH to near 100 percent, which allows more water to be removed by the desiccant materials in the 4BMS. The desiccant materials are in separate canisters from the CO_2 sorbent so that water can be desorbed separately from the CO_2, and the water returned to the habitat atmosphere.

The cooler temperature inlet atmosphere also increases the adsorption capacity of the CO_2 sorbent materials. Prior to opening the CO_2 vent valve to desorb the CO_2 to space, the air-save pump removes residual atmosphere from the CO2 sorbent bed and returns it to THCS.

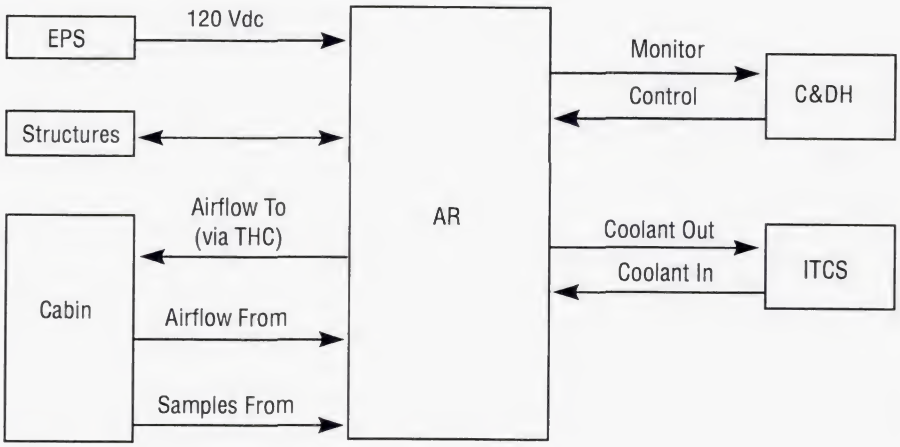
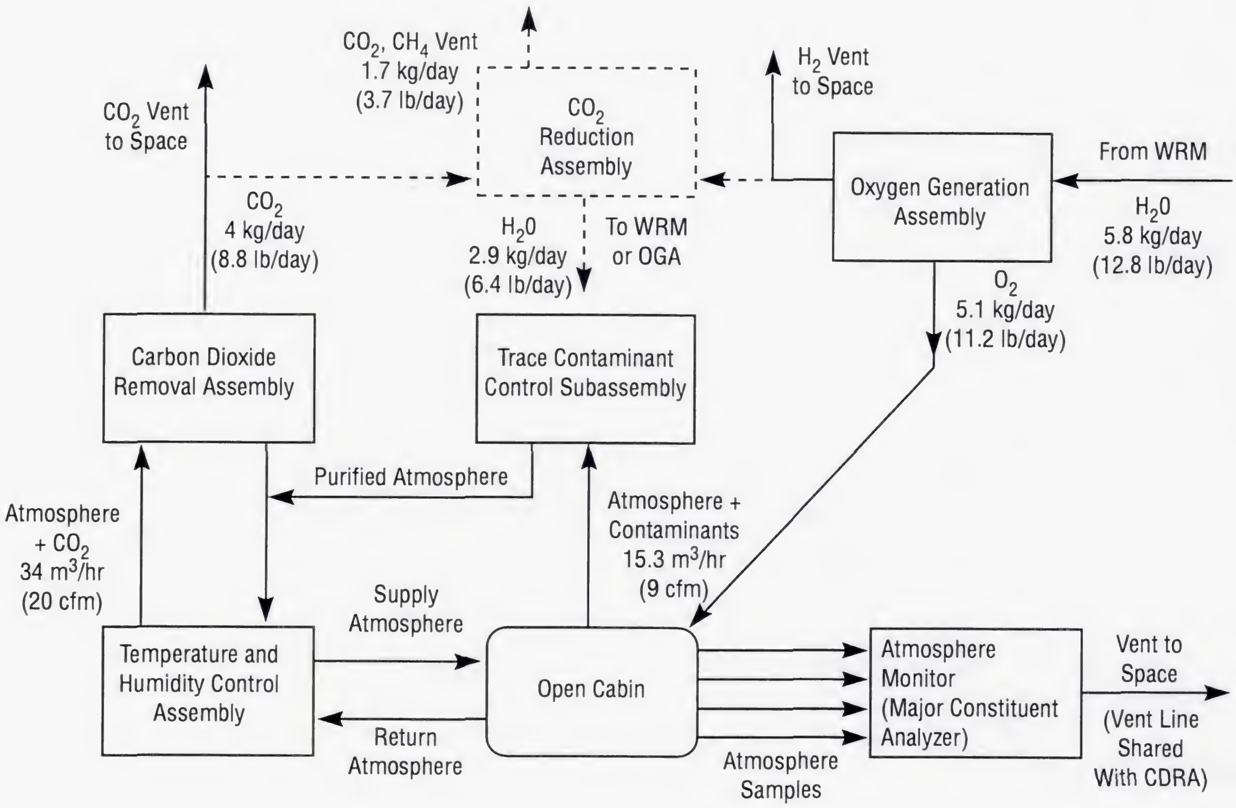


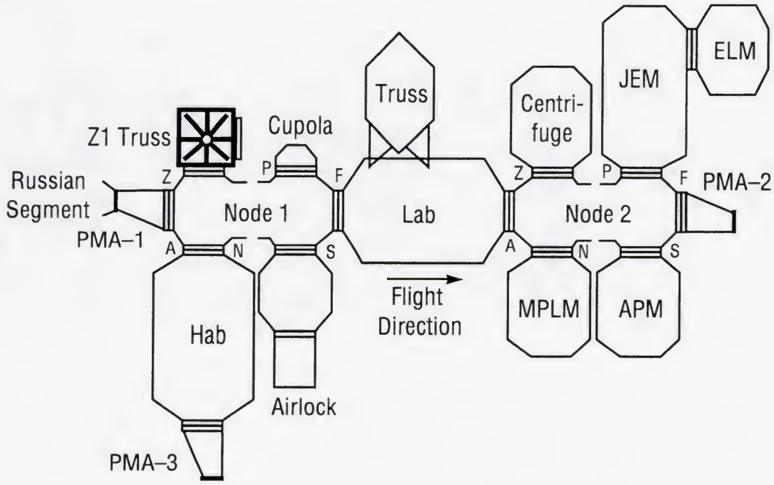
FIGURE 73.—USOS AR subsystem interfaces.



CO_2 reduction is not included initially, but the capability to add it later may be included.

FIGURE 74.—Diagram of the USOS AR subsystem.

Legend



- Self-Sealing Quick Disconnect, Half
- Non-Sealing Quick Disconnect, Half
- Flex Hose
- Mechanical Fitting, Half
- Manual Valve
- Solenoid Valve (2-Way) with Manual Overide and Position Indication
- Solenoid Valve (3-Way) with Manual Override and Position Indication
- Sample Probe

- Non-Propulsive Vent
- Feedthrough
- Filter
- Sample Port
- Oxygen Partial Pressure Sensor
- Carbon Dioxide Partial Pressure Sensor
- Water Vapor Partial Pressure Sensor
- 1 LiOH Used for CO_2 Removal During Airlock Campout

FIGURE 75.—AR subsystem.

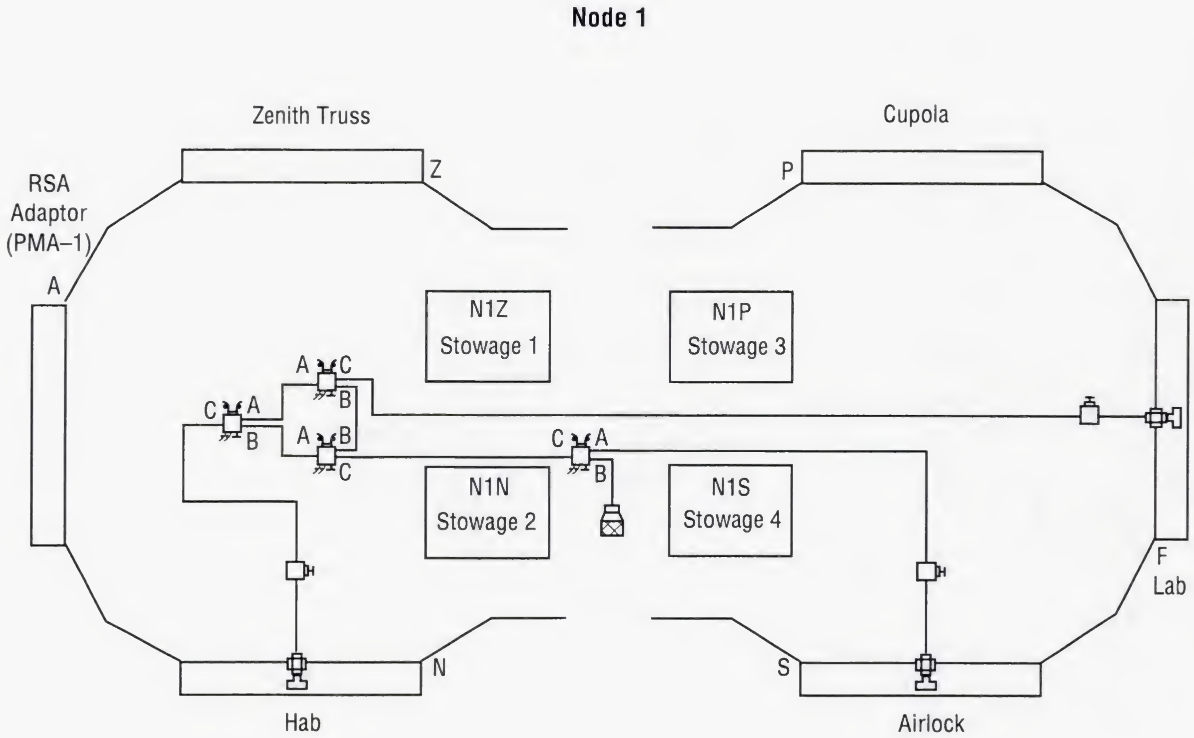


FIGURE 76.—AR subsystem (continued).

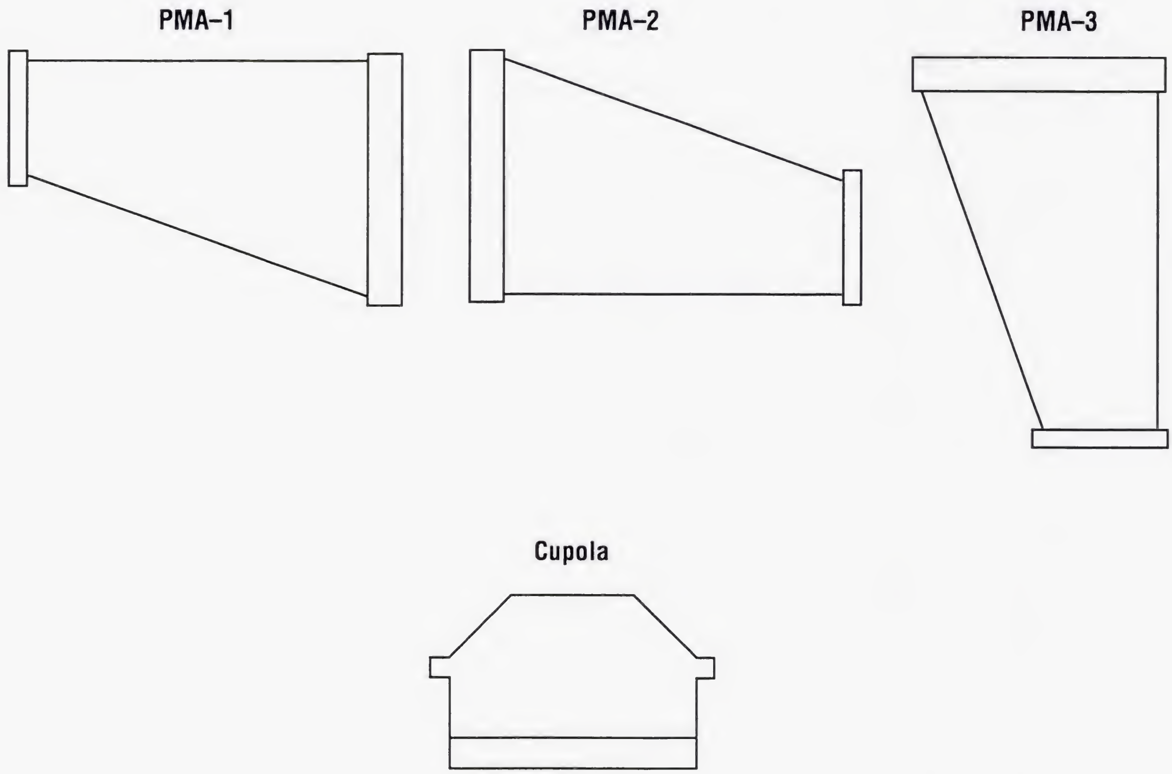


FIGURE 77.—AR subsystem (continued).

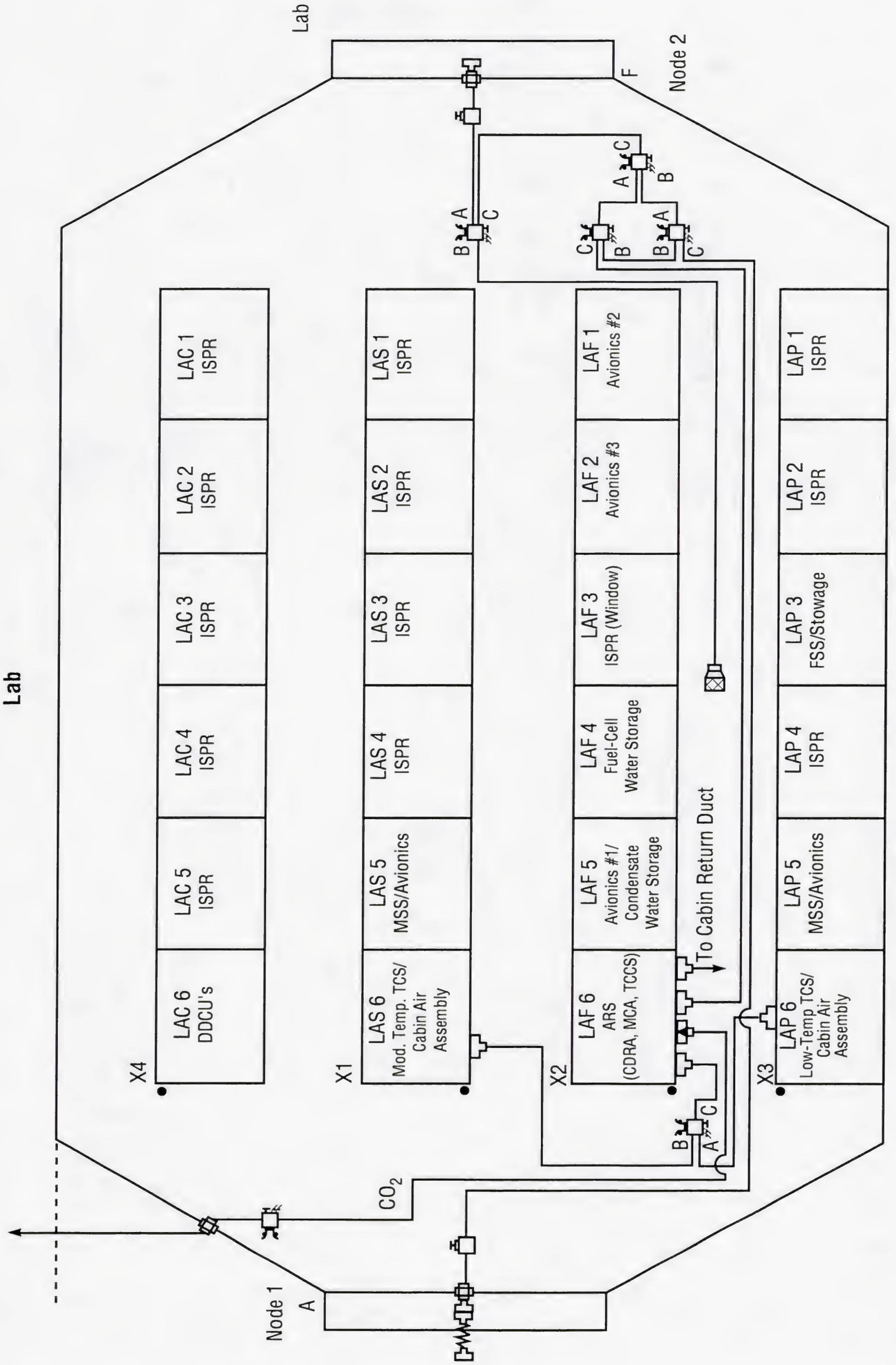
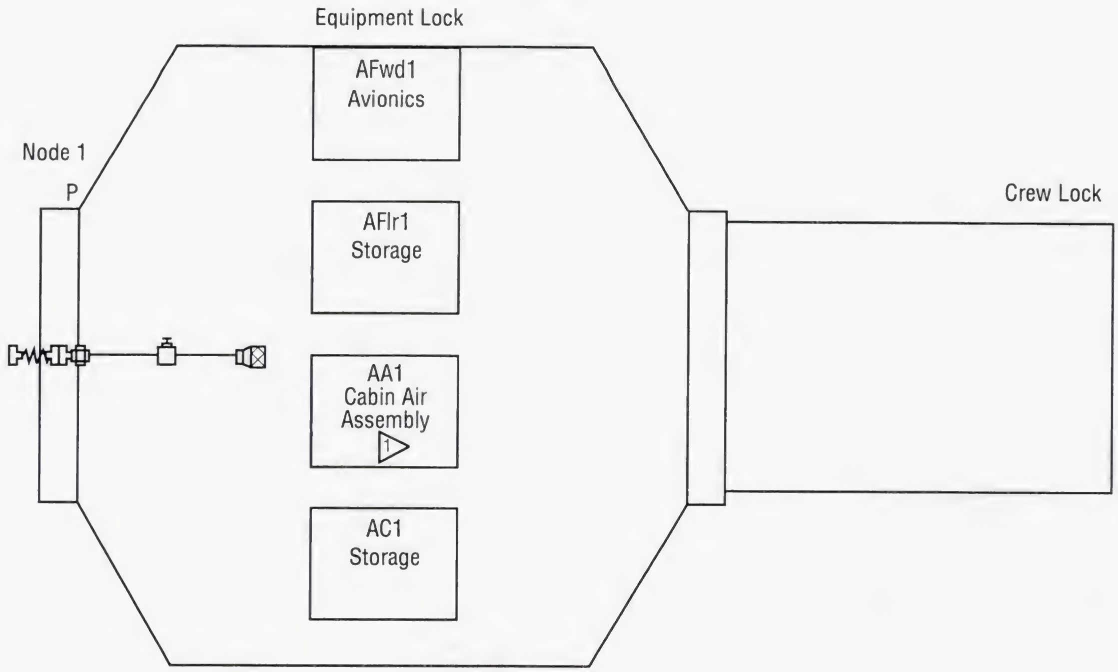


FIGURE 78.—AR subsystem (continued).

Airlock



Centrifuge

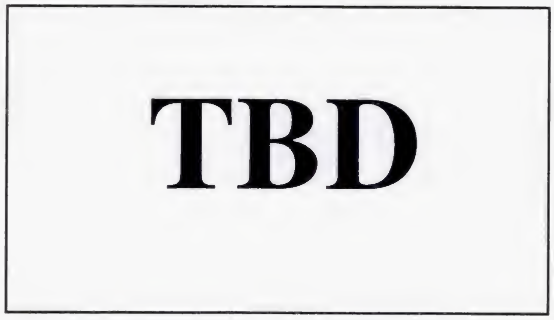


FIGURE 79.—AR subsystem (continued).

The physical interfaces of the 4BMS are as follows:

- Fluid interfaces
  - Process air supply and return
  - ITCS coolant supply and return vacuum vent
  - Vacuum Vent
- Electrical interfaces
  - 3 data connectors
  - 4 power connectors
- Structural interfaces
  - 36 mechanical interfaces: 6 bolts per post, 2 posts per slide, 3 slides.

Sensors are used to measure the conditions of the fluids in the 4BMS and the status of the components as follows:

- 12 selector valve position indicators (digital)
- 6 selector valve motor speed sensors (digital)
- 1 pump motor speed sensor (digital)
- 1 blower motor speed sensor (digital)
- 2 integrated circuit temperature sensors (analog cut-off)

Node 2

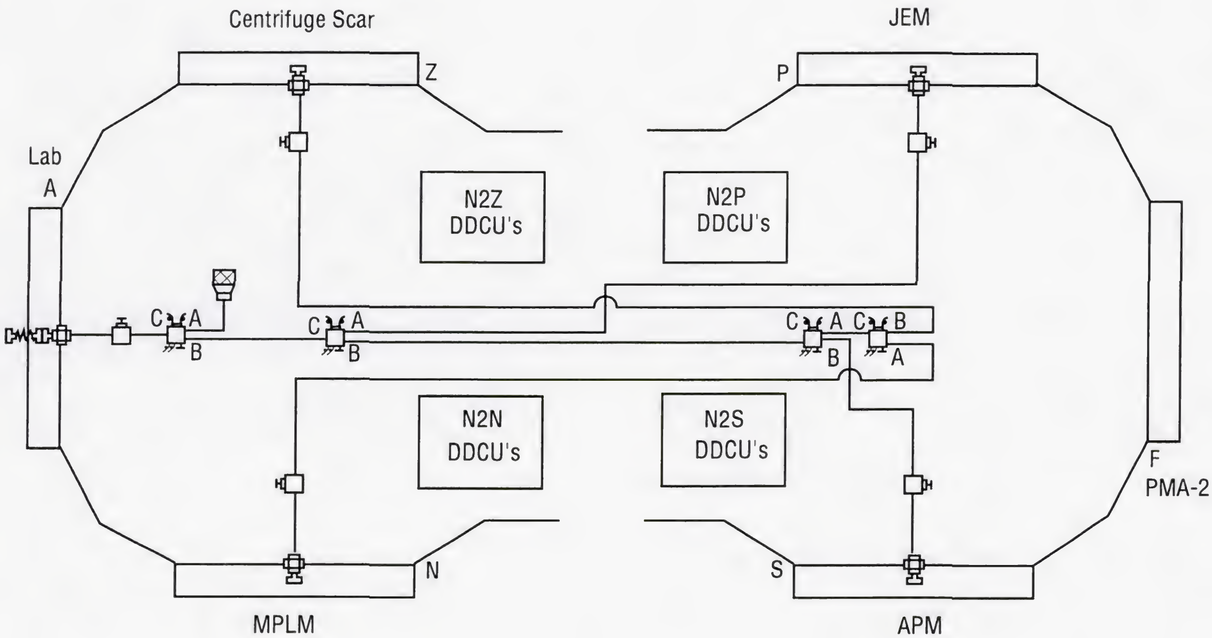


FIGURE 80.—AR subsystem (continued).

- 6 CO_2 adsorbent bed temperature sensors (analog cut-off)
- 3 stand-alone air temperature sensors (analog data and Fault Detection and Isolation (FDI))
- 1 stand-alone absolute pressure sensor (analog data and FDI)
- 1 stand-alone differential pressure sensor (analog data and FDI)
- Total = 33 sensors = 28 discrete functions and 5 analog data.

Note that no critical control actions depend on calibrated analog readings. Sensor specifications are listed in table 23.

Components of the 4BMS are:

- ORU's:
  - Selector valve (five)
  - Desiccant bed/adsorbent bed/air check valve (two)
  - Blower/precooler/selector valve (one)
  - Two-stage pump (one)
  - Motor controller (two)
  - Heater controller (two)
- Temperature sensor (three)
- Absolute pressure sensor (one)
- Electronics cold plate (one)
- Structure
- Electrical wiring harness
- Tubing
- Application software.
- Differential pressure sensor (one).

The power consumption and masses of 4BMS components are listed in tables 24 and 25, respectively. The thermal interfaces and loads are shown in figure 85.

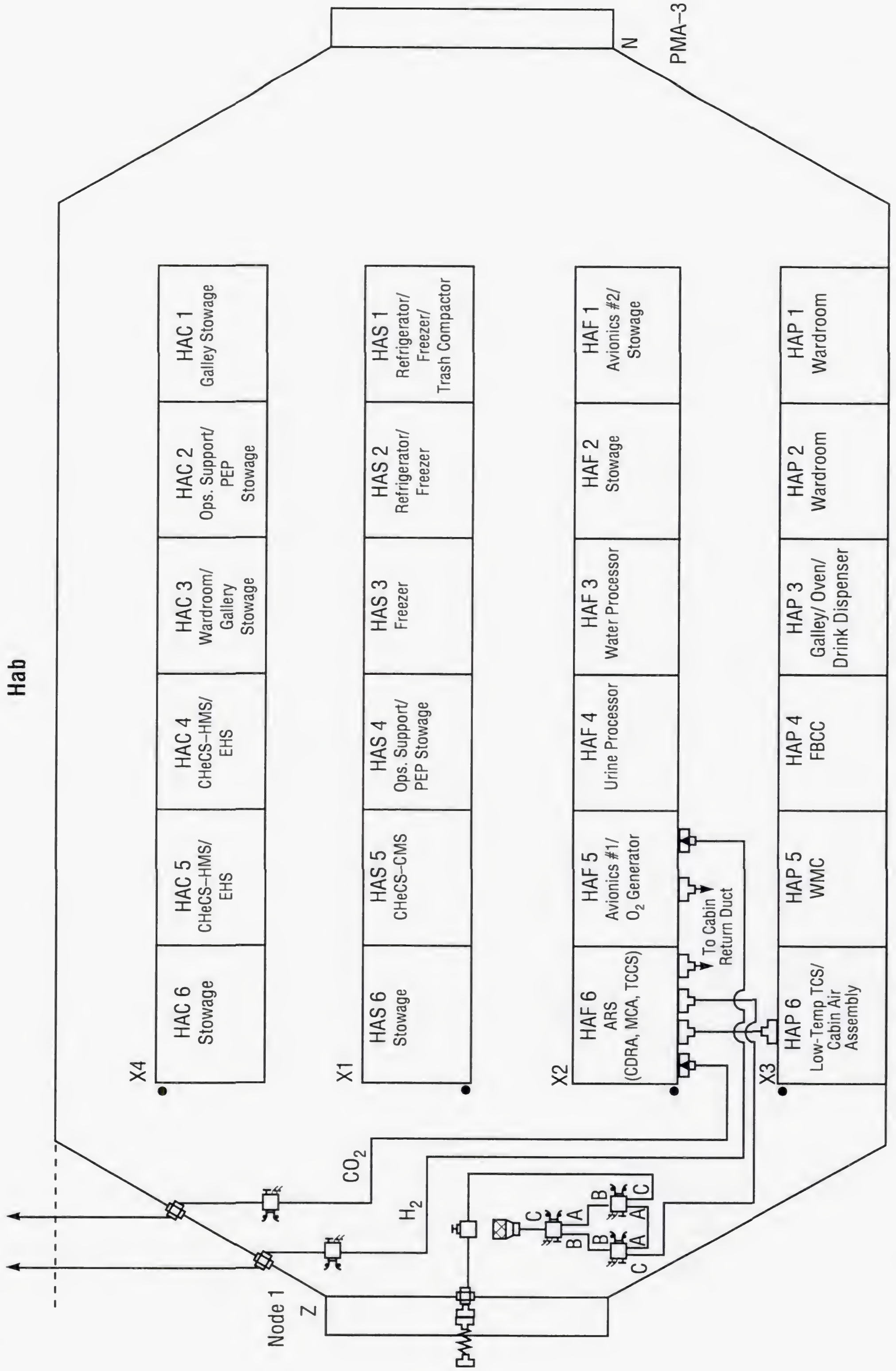
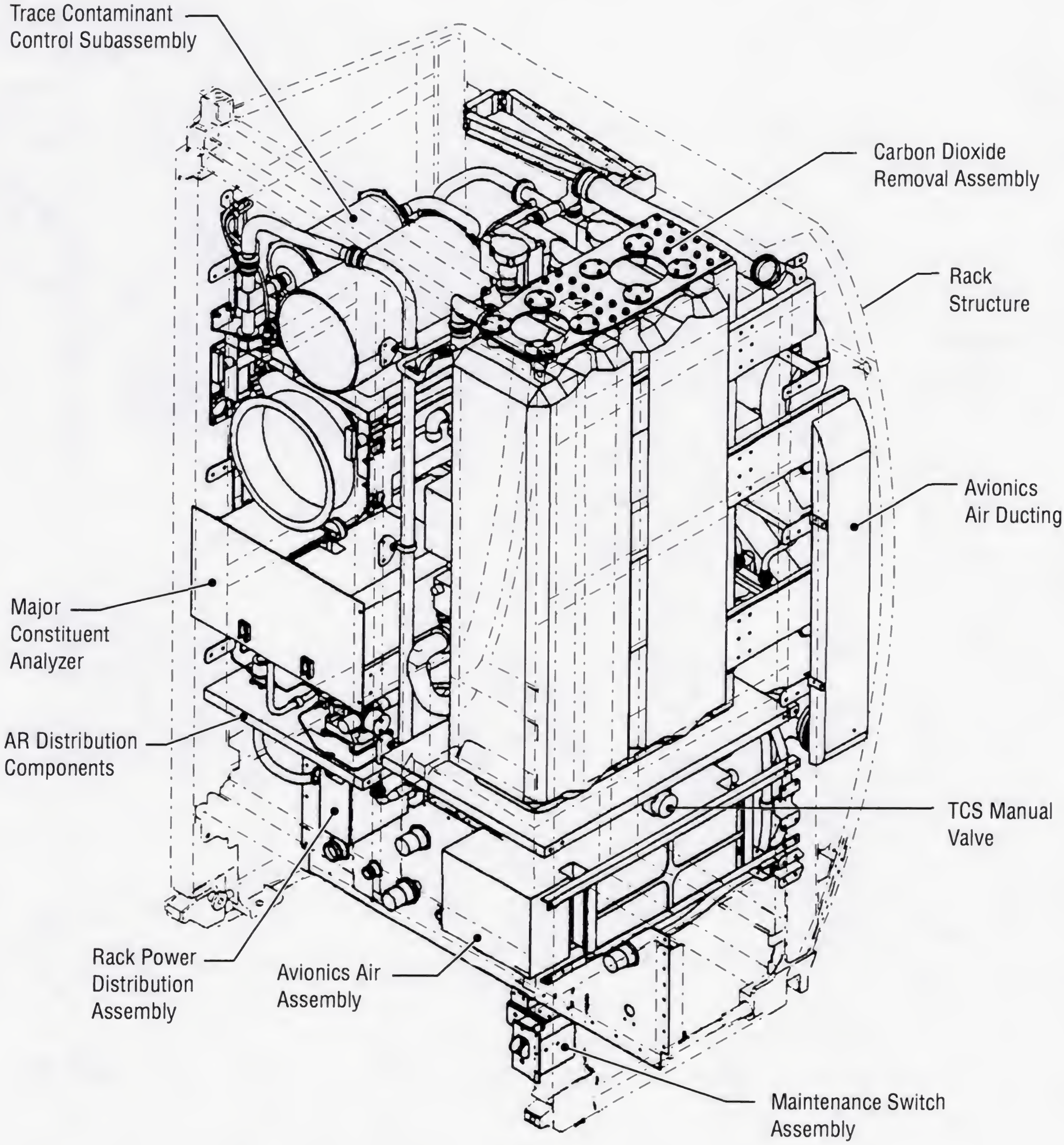
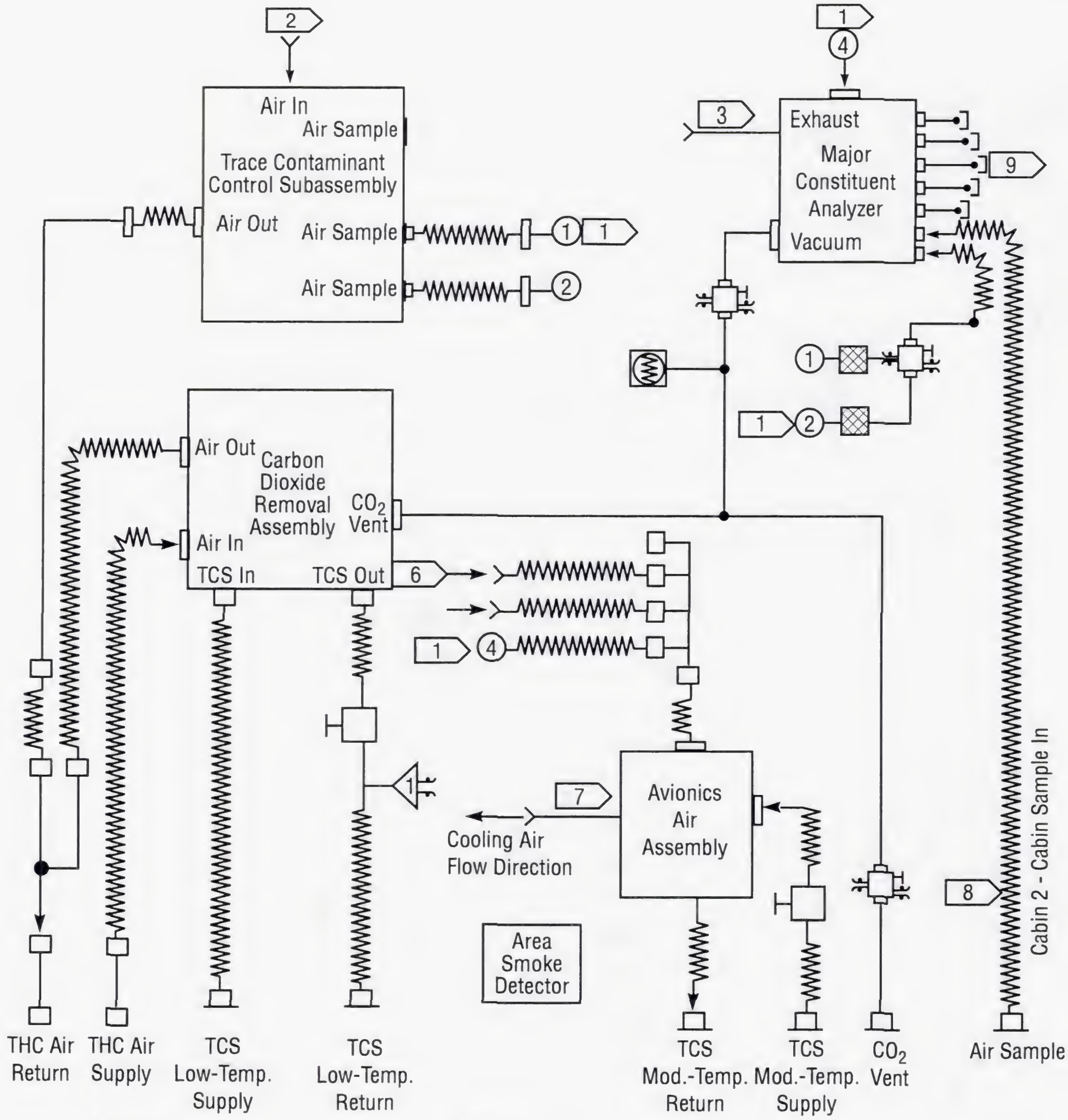


Figure 81.—AR subsystem (continued).



AR Rack Front Isometric View
(Rack Faceplate Not Shown for Clarity)

FIGURE 82.—USOS AR rack packaging in the Lab (the Hab AR will also include an OGA).



Legend

- Manual Valve
- Solenoid Valve with Manual Override and Position Indication
- Pressure Transducer
- Diffuser
- Flexible Hose
- Seven Port Quick Disconnect Half
- Rigid Tubing
- Tee Fitting
- Quick Disconnect Half
- Mechanical Connector Half
- Subassembly Envelope
- Filter
- Capped Line
- Area Smoke Detector — Smoke Detector
- Mod — Moderate
- Temp — Temperature

Notes

1. Line continuation numbers correspond to matching locations within the rack.
2. The TCCS draws air directly from the face of the rack using a duct within the subassembly. The rack closeout panel will include a protective screen at the TCCS inlet location.
3. The MCA exhausts air directly into the rack.
5. Subassembly interface designators are as follows:
   AA–Carbon Dioxide Removal Assembly
   AD–Trace Contaminant Control Subassembly
   AC–Stand–alone major constituent analyzer
6. Avionics air suction diffusers are located throughout the rack.
7. Avionics air supply is exhausted directly into the rack.
8. The flexible hoses on the air sample lines are a part of the rack bulkhead connector.
9. The unused sample ports are capped.

Figure 83.—Schematic of AR rack assembly connections.

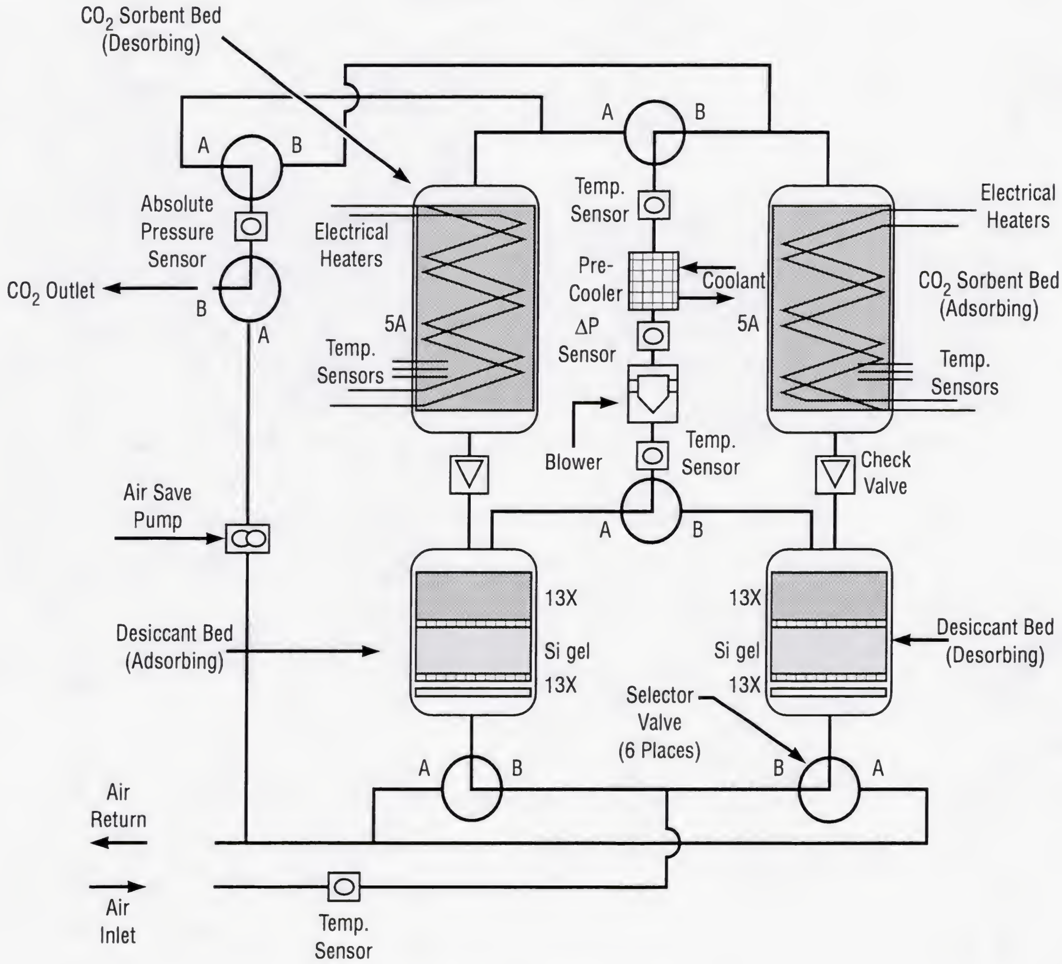


FIGURE 84.—4BMS CDRA.

TABLE 23.—*4BMS sensor specifications.*

Sensor	Sensor Type	Output	Power Input	Accuracy
Temperature	PRTD (1,000Ω)	1 to 2 Vdc	1 mA	±1 °C (±2 °F) Data & FDI ±3 °C (±5 °F) Discrete Function
Inverter Chip Temperature Sensor	Two Terminal Integrated Circuits	Current 298.2 μA at 25 °C (77 °F)	4 to 30 Vdc	±1 °C (±2 °F) Discrete Function
ΔP	Variable Reluctance Strain Gauge	–5 to 5 Vdc 0 to 1.3 m H_2O (50 in H_2O)	15 Vdc, 20 mA (max)	±0.65% FS Data and FDI
Absolute Pressure	Variable Reluctance	–5 to 5 Vdc Strain Gauge (20 psia)	15 Vdc, 20 mA (max) 0 to 138 kPa	±0.65% FS Data and FDI
Valve Position Indicator	Optical-Interruptor Light-Emitting Diodes (LED)	Digital A or B Position 13.5 to 17.1 Vdc—on, 0 Vdc—off	Integral With Valve Assembly Power	Digital
Motor Speed	Hall-Effect Sensor	20 mA—on, 0 mA—off	Integral With Motor	Digital

TABLE 24.—*4BMS power consumption.*

Component Description	Total Power Consumption, W	Total Power Consumption, Time-Averaged W
Selector Valves	60	<1
Blower	58	58
Blower Motor Controller	5	5
Adsorbent Bed Heater	480	390
Heater Controller	19	19
Pump	226	19
Pump Motor Controller	20	2
Sensors	3	3
4BMS Total Power Consumption (Time-Averaged)		497

TABLE 25.—*4BMS mass properties.*

Component Description	Quantity per 4BMS	Unit Mass		Summed Mass	
		kg	lb	kg	lb
• Air Selector Valve	6	2.6	5.7	15.5	34.2
• Desiccant/Adsorbent Unit					
– Desiccant Bed	2	17.3	38.0	34.5	76.0
– Adsorbent Bed	2	23.6	52.0	47.2	104.0
– Air Check Valve	2	0.1	0.3	0.3	0.6
– Heater Controller	2	3.3	7.3	6.6	14.6
• Blower/Precooler Unit					
– Air Blower	1	1.0	2.2	1.0	2.2
– Motor Controller	1	1.3	2.8	1.3	2.8
– Precooler	1	2.7	6.0	2.7	6.0
• CO_2 Pump Unit					
– CO_2 Pump	1	8.2	18.0	8.2	18.0
– Motor Controller	1	1.3	2.8	1.3	2.8
• Sensors					
– Temperature Sensor	3	0.1	0.3	0.4	0.9
– Differential Pressure Sensor	1	0.2	0.5	0.2	0.5
– Absolute Pressure Sensor	1	0.2	0.5	0.2	0.5
• Electrical Harness	1	4.5	10.0	4.5	10.0
• Plumbing	1	5.9	12.9	5.9	12.9
• Support Structure	1	36.1	79.5	36.1	79.5
• Fluid Disconnects	4	0.6	1.4	2.5	5.6
• Electronics Cold Plate					
– Cold Plate	1	3.3	7.3	3.3	7.3
– Interface Plate	2	0.8	1.7	1.5	3.4
4BMS Total Mass				**173.3**	**381.8**

The 4BMS components and ORU's are described below.

Selector Valves—The direction of flow of air and CO_2 is controlled by valves. The valve design requirements are:

- Operating fluid
  - Atmosphere (0 to 100 percent RH) and CO_2
- Flowrate
  - 0 to 58.5 kg/hr (0 to 129 lb/hr) of air and 0 to 4.1 kg/hr (0 to 9 lb/hr) of CO_2
- Maximum pressure drop
  - 1.27 cm (0.5 in) of water at 45.5 kg/hr (100 lb/hr) airflow

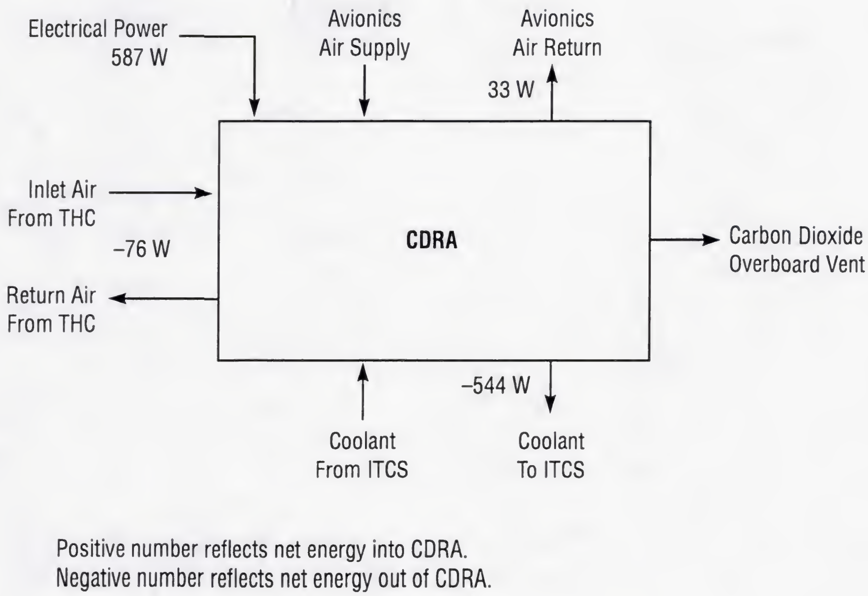


FIGURE 85.—4BMS interfaces and time-averaged thermal loads.

- Total leakage
  - 0.5 sccm air at 689.5 kPa (100 psid)
- Closing time
  - 6 sec (maximum).

The design and construction characteristics of the selector valves are:

- Mass
  - 2.04 kg (4.5 lb) (maximum, including actuator)
- Line size
  - 3.8 cm (1.5 in) outer diameter
- End fitting
  - Hydraflow
- Voltage
  - 120 Vdc
- Position indicator
  - End of travel
- Dynamic shaft seals
  - Dual seals.

Desiccant Bed/CO_2 Adsorbent Bed—The desiccant beds and CO_2 adsorbent beds are combined into ORU's, each consisting of one desiccant bed and one CO_2 sorbent bed, as shown in figure 86. The characteristics and design requirements of these ORU's are:

- Operating fluid
  - Air and CO_2
- Flowrate
  - 19.5 to 40.8 kg/hr (43 to 90 lb/hr) of air
- Operating fluid temperature
  - 4.4 to 204.4 °C (40 to 400 °F)
- Operating fluid pressure
  - 3.4 to 104.8 kPa (0.5 to 15.2 psia)
- Desiccant bed material:
  - Molecular sieve 13X 290 cc
  - Si gel 6,600 cc
  - Molecular sieve 13X 5,900 cc
- CO_2 Adsorbent bed material:
  - Molecular sieve 5A 16,000 cc
- Nominal heater power:
  - Primary 480 W
  - Secondary 480 W
- Temperature sensor resistance
  - 1,000 ohms at 0 °C (32 °F).

Air Check Valves—The air check valves isolate the process air loop from the CO_2 loop during CO_2 adsorbent bed regeneration, i.e., they stop the airflow from the adsorbing desiccant bed to the desorbing sorbent bed. The valves are spring loaded flapper type, as shown in figure 87. The design requirements of these valves are:

- Flowrate
  - 18.1 to 54.4 kg/hr (40 to 120 lb/hr)
- Inlet temperature
  - 1.7 to 65.6 °C (35 to 150 °F)
- Leakage
  - 0.5 SCCM at 99.9 kPa DP (14.5 psid)
- Fluid
  - Air and CO_2
- Maximum pressure drop
  - 1.3 cm (0.5 in) of water at 41 kg/hr (90 lb/hr).

Heater Controller—The heater controller supplies power to the heaters in the CO_2 sorbent beds and has the following design characteristics:

- Power input
  - 120 Vdc for the primary heater
  - 120 Vdc for the secondary heater
- MDM interface
  - Discrete on/off commands (primary and secondary)
  - Enable commands (primary and secondary)
  - Temperature feedback (T_1, T_2, and T_3)
- Heater interface
  - 12 primary elements (40 W each)
  - 12 secondary elements (40 W each) Maximum power output = 960 W
  - 3 temperature probes (T_1, T_2, and T_3).

Precooler—The precooler, shown in figure 88, removes motor and compression heat generated by the blower and removes the heat of adsorption resulting from water removal in the desiccant bed. The cooled air permits greater carbon dioxide adsorption. The design requirements are:

- Air side:
  - Airflow = 41 kg/hr (90 lb/hr) (max)
  - Inlet temperature = 65.5 °C (150 °F) (max)
  - Outlet temperature = 10 °C (50 °F) (max)
  - Pressure drop = 1.3 cm (0.5 in) H_2O at 41 kg/hr (90 lb/hr)
- Coolant side:
  - Water flow = 119 kg/hr (262 lb/hr) (nominal)
  - Inlet temperature = 4.4 °C (40 °F) (nominal)
  - Outlet temperature = 7.2 °C (45 °F) (max)
  - Pressure drop = 12.4 kPa (1.8 psid) (max).

The design has the following features and characteristics:

- Stainless steel housing
- Stainless steel plate fin heat exchanger core:
  - Single-pass air
  - Double-pass water
- Mass = 2.7 kg (6 lb).

Blower Assembly—The blower assembly, shown in figure 89, provides air circulation through the 4BMS to overcome system pressure drop and the THC interface pressure drop. The design requirements for the blower assembly are:

- Flow
  - 41 kg/hr (90 lb/hr)
- Total pressure rise
  - 64 cm (25.2 in) of water
- Duty cycle
  - 100 percent
- Speed
  - 115,000 rpm
- Motor
  - 120 Vdc
- Motor speed sensor for FDI and control.

Air-Save Pump—The air-save pump, shown in figure 90, removes most of the air from a CO_2 adsorbent bed prior to desorption to space vacuum. The design requirements for the pump are:

- Operating fluid
  - Air (0 to 100 percent humidity) and CO_2
- Maximum CO_2 adsorbent bed pressure at air save cycle end
  - 3.4 kPa (0.5 psia)
- Coolant inlet temperature
  - 7.2 °C (45 °F)
- Coolant loop pressure drop
  - 3.8 kPa (0.55 psid)
- Operating fluid temperature
  - 3.3 to 71 °C (38 to 160 °F)
- Operating fluid pressure
  - 3.4 to 104.8 kPa (0.5 to 15.2 psia)
- Operating time
  - 15 min of every half-cycle
- Operating power
  - 226 W.

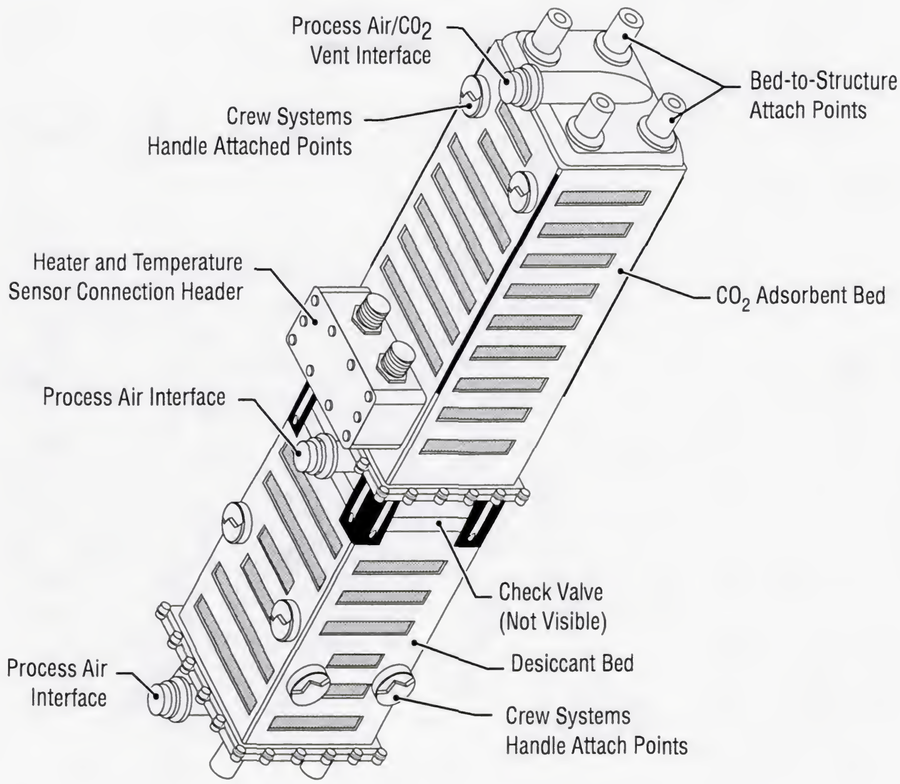


FIGURE 86.—4BMS desiccant bed/CO_2 adsorbent bed ORU.

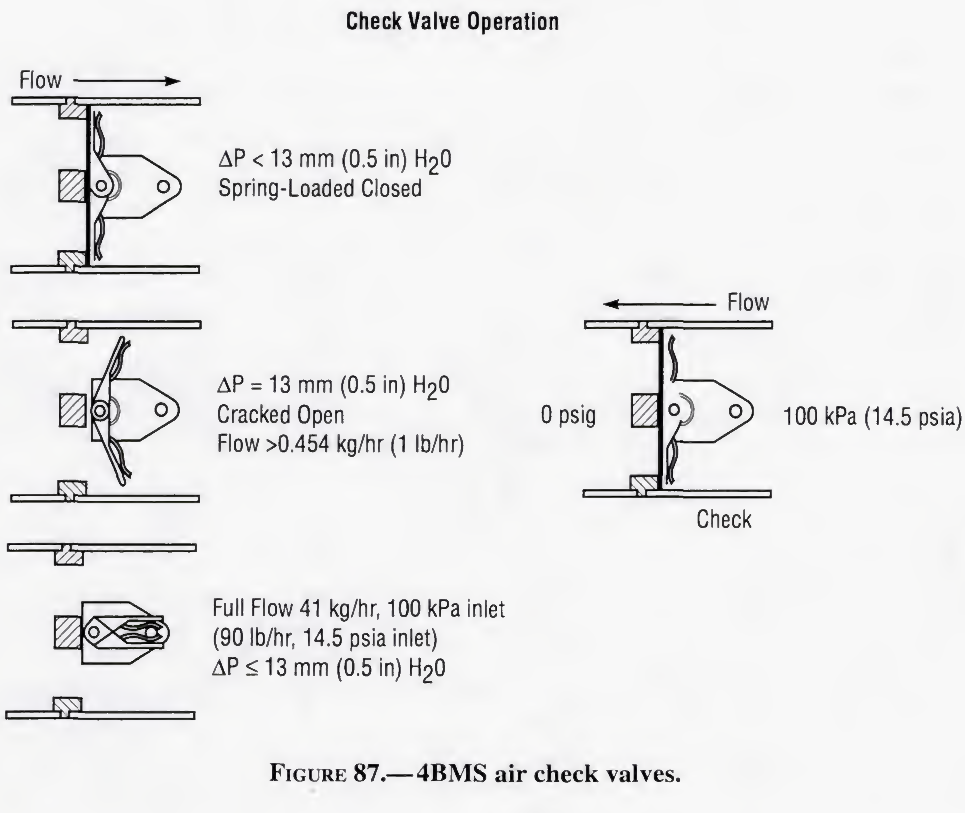


FIGURE 87.—4BMS air check valves.

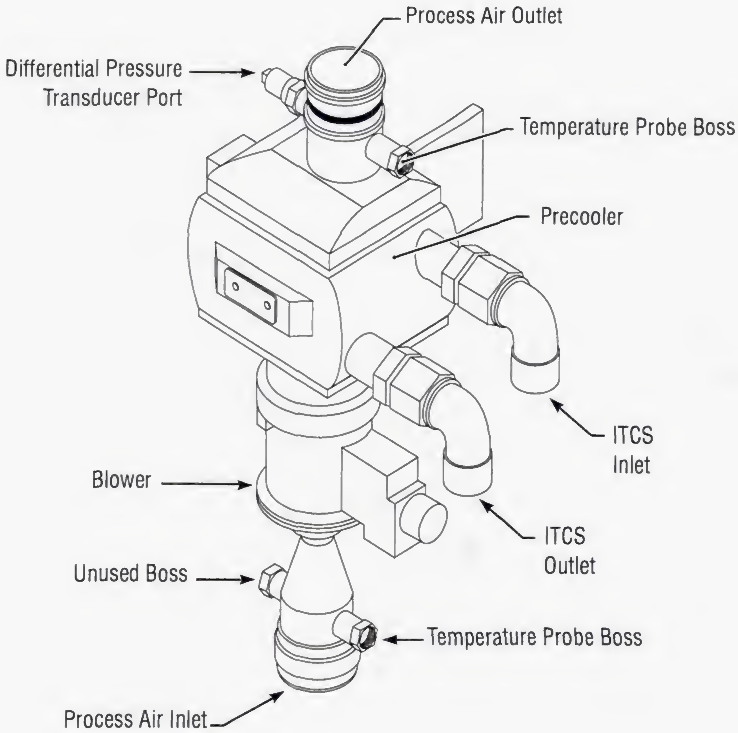


FIGURE 88.—4BMS precooler.

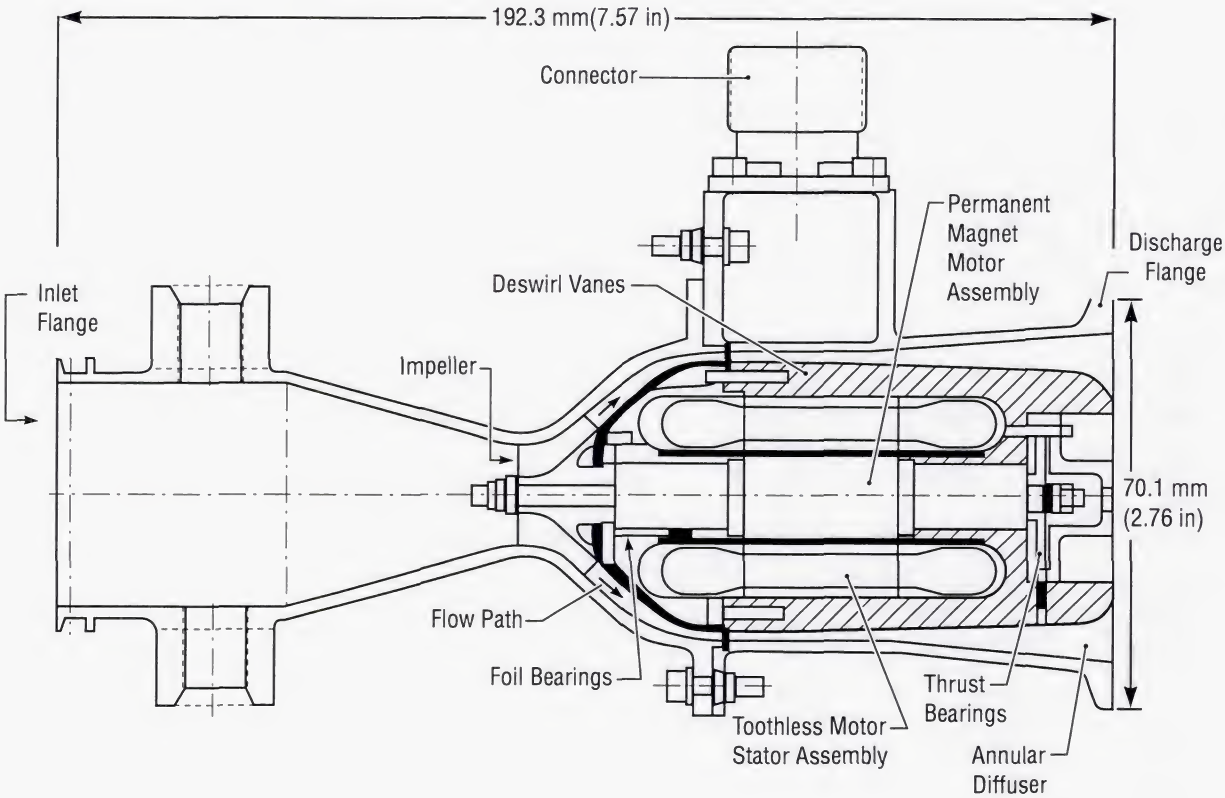


FIGURE 89.—4BMS blower assembly.

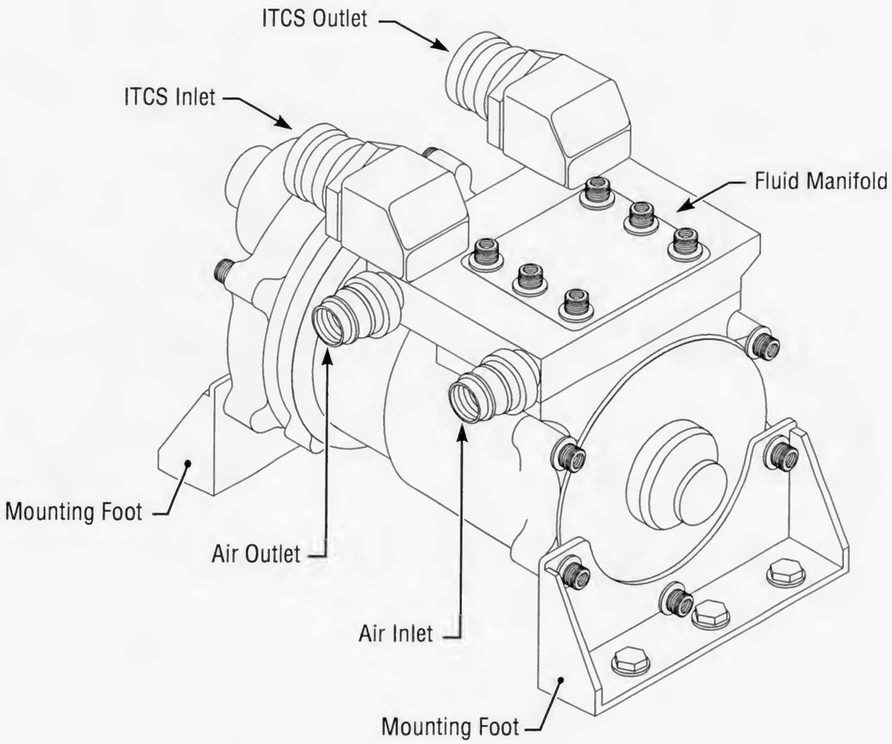


FIGURE 90.—4BMS air-save pump.

Pump/Fan Motor Controller—The pump and fan controller has the following characteristics:

- Electrical characteristics
  - MDM interface:
    MIL–STD–1553 Data Bus
  - Motor interface:
    Three-phase dc brushless, eight configurations
  - Input power: 120 Vdc
  - Power dissipation: 40 W max
- Mechanical characteristics
  - Mounting:
    Four-bolt attachment to adapter plate on cold plate
  - Thermal:
    - 20 to 43 °C (68 to 109 °F) ambient,
    - cold plate is water cooled,
    - flowrate 119 kg/hr (262 lb/hr),
    - water inlet temperature 13 °C (55 °F)
  - BIT:
    Monitor motor speed, motor current, inverter temperature, and dc-link voltage
- Speed and torque limits
  - Programmable.

4BMS Reliability—The expected lifetimes of the 4BMS components are listed in table 26.

Table 26.—*4BMS limited life items.*

ORU	Limited Life Items	Life Limit
Selector Valve	Actuator Gears	> 30 yr
Desiccant/Adsorbent Unit	Check Valves	20 yr
Blower/Precooler Unit	Foil Bearings	> 30 yr
Pump	Vanes	10 yr
Temperature Sensor	No Moving Parts	
Pressure Sensor	No Moving Parts	

4BMS Maintainability—There are no regular maintenance items in the 4BMS. In the event that a failure occurs, the failed ORU would be replaced. The amount of time required to replace an ORU depends on which one needs to be replaced. All the ORU's are mounted so that they can slide out for easy access, to require minimal time for replacement. For example, to replace a leaking air check valve would require no more than 2 hr for the complete procedure. (See section 5.1.1 for more information on repair procedures.)

3.3.1.2.2 4BMS Operation

The operational conditions for the CDRA are listed below:

- Inlet temperature
  - 4.4 to 10.0 °C (40 to 50 °F)
- Inlet dewpoint
  - 4.4 to 10.0 °C (40 to 50 °F)
- RH
  - ~100 percent
- ppO_2
  - 19.5 to 23.1 kPa (2.83 to 3.35 psia)
- Total pressure
  - 99.9 to 104.8 kPa (14.5 to 15.2 psia)
- Entrained water droplets
  - 0.143 g/kg dry air (1.0 gr/lb dry air)
- $ppCO_2$ (maximum)
  - 0.71 kPa (5.3 mmHg)
- Diluent gas
  - Nitrogen.

The 4BMS operational states and the possible transition paths are shown in figure 91. The states are defined in table 27. The operating sequence is shown in figure 92.

Table 27.—*4BMS states.*

Operating States	
Normal	4BMS operates using two half-cycles and three segments per half-cycle.
Startup	4BMS operates using two half-cycles and three segments per half-cycle, but the sequencing of the equipment is different than during the normal state.
Nonoperating States	
Off	4BMS is unpowered and awaiting Initialize command.
Inactive	4BMS has been powered, initialized, and is awaiting a Normal, Standby, or BIT command. Sensor readings are not available.
Cold Standby	4BMS has been shut down for more than 1 hr.
Warm Standby	4BMS has been shut down for less than 1 hr.
Test	State that allows the 4BMS to be initialized and a BIT to be performed.
Failed	A failure has been detected in the 4BMS; automatically transitions to Off if in the Failed state for more than 1 hr.

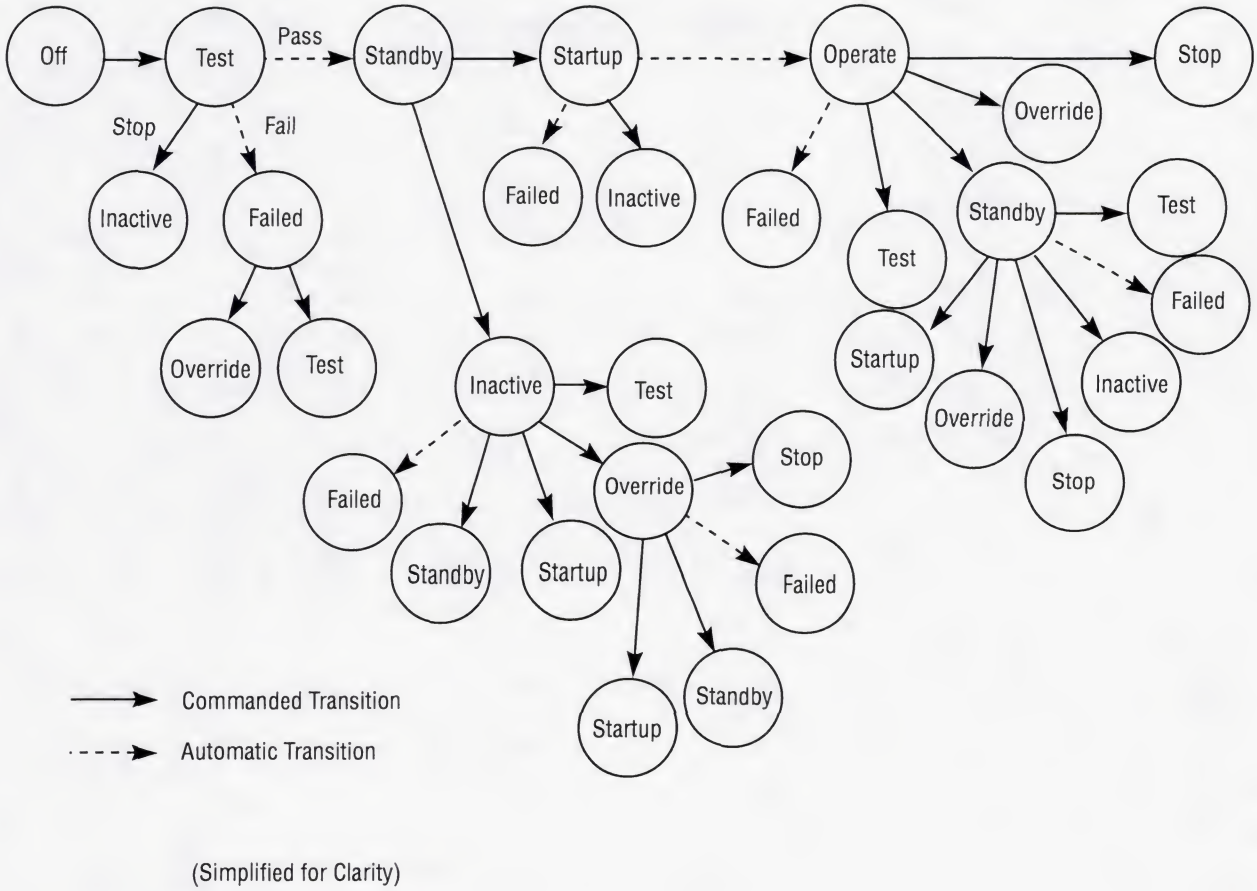


FIGURE 91.—4BMS operational states and transition paths.

3.3.1.2.3 4BMS Performance

The CO_2 removal rate follows the graph shown in figure 93. The requirements for the purity of the concentrated CO_2 are:

- Less than 1 percent by volume oxygen.
- Less than 2 percent by volume nitrogen.
- Less than 18.3 °C (65 °F) dewpoint (defined by the desiccant bed performance analysis). (This is the reason that the inlet to the 4BMS is downstream of the CHX; however, the performance of the 4BMS is less sensitive to the presence of H_2O than to loss of coolant.)

3.3.1.3 Dispose of CO_2

The CO_2 that is removed from the atmosphere by the 4BMS is vented to space through a dedicated vent, as shown in figures 78 and 81.

3.3.2 Control Gaseous Contaminants

The presence and concentrations of atmospheric contaminants are monitored and excess contaminants are removed from the habitat atmosphere.

3.3.2.1 Monitor Gaseous Contaminants

Major constituents are continuously monitored in the *ISS* atmosphere, including the European, Japanese, Italian, and U.S. modules. The SDS provides the sample ports at the desired sampling locations. Samples are collected in sequence from the different ports once each minute and are analyzed for O_2, N_2, CO_2, H_2, CH_4 and H_2O. The capability for rapid sampling is also available (every 2 sec from a single port). The information on the atmospheric composition is used to monitor or operate the ACS, CDRA, and TCCS. The measurement of H_2O is for information only due to concern about inaccurate readings because of condensation in the lines.

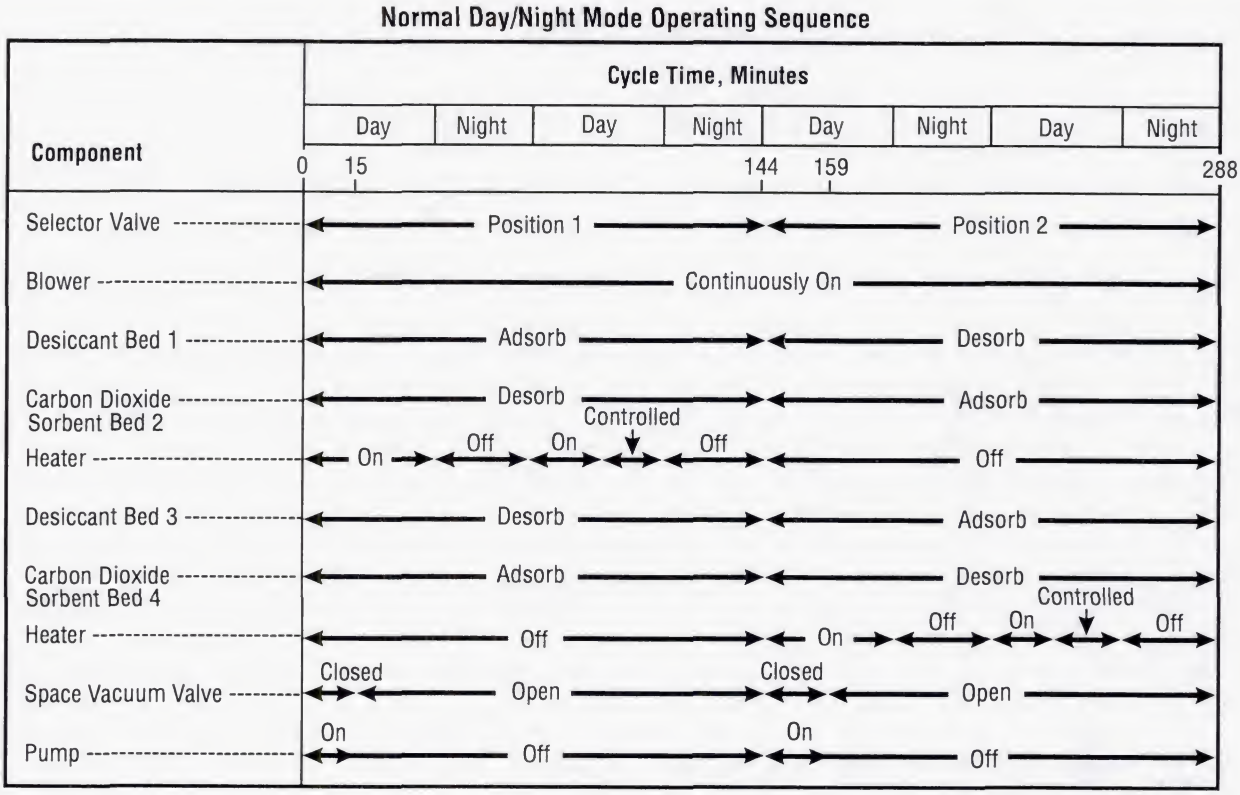


FIGURE 92.—4BMS operating sequence.

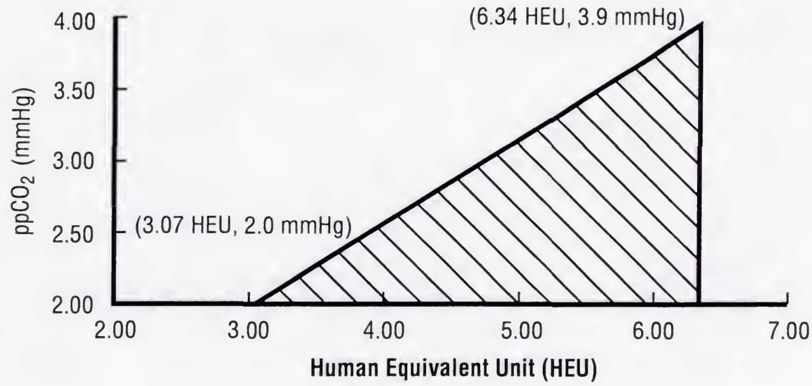
3.3.2.1.1 Major Constituent Analyzer (MCA) Design

A schematic of the MCA process is shown in figure 94. The MCA has the following characteristics:

- Mass
  – 54 kg (119 lb),
- Power Consumption
  – 103.3 W
- Volume
  – 0.081 m^3 (2.85 ft^3)

As shown in figure 95, the MCA hardware consists of seven ORU's having the following functions:

- Data and control assembly (firmware controller)—command and data handling (C&DH) interface
- Mass Spectrometer (MS) assembly—Sample analysis
- Low voltage power supply—Converts 120 Vdc to the required MCA voltages. Provides low-voltage power for analog to digital converters, power converters, electrometers, and mechanical items
- Series pump assembly—Draws samples through the MCA:
  – Maintains 53.3 kPa (400 torr or 7.7 psia) at the MS inlet and 600 cc/min flow through the sample lines
  – The pump has a mass of 1.7 kg (3.8 lb) and consumes 4.9 W of power
- Inlet valve assembly—Selects sample ports
- EMI filter assembly—Filters 120 Vdc supplied by the *ISS*
- Verification Gas Assembly—Used to calibrate the MS.



Notes:

(1) The area below the line defines the CO_2 removal performance region.
(2) 1.0 HEU = 1.0 kg/person/day (2.2 lb/person/day) CO_2 removed.
(3) The equation of the line is defined by:
$$\text{HEU} \geq 1.723\ ppCO_2\ (\text{mmHg}) - 0.37975 \text{ for } 2.0 \leq ppCO_2 \leq 3.9$$

FIGURE 93.—CO_2 removal performance requirement.

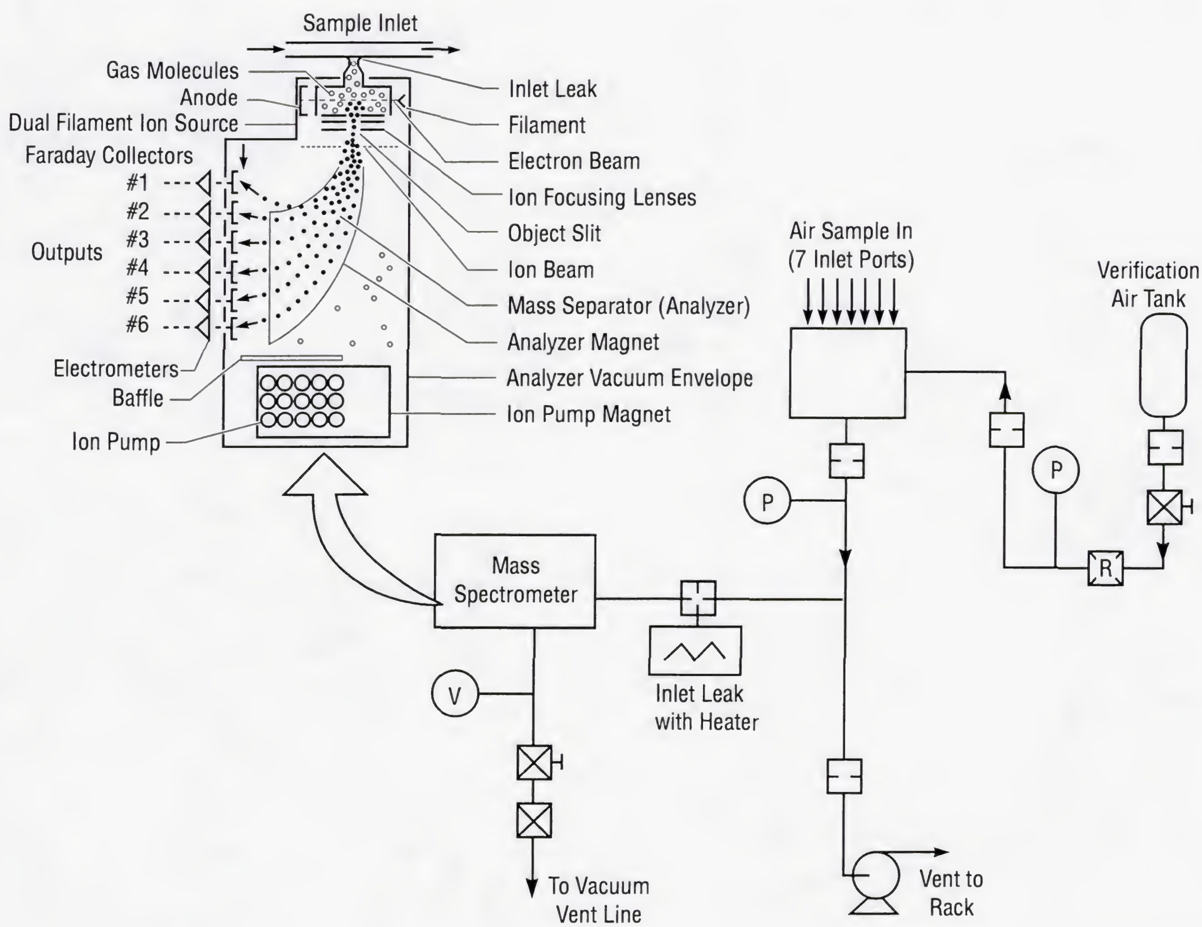


FIGURE 94.—Schematic of the MCA process.

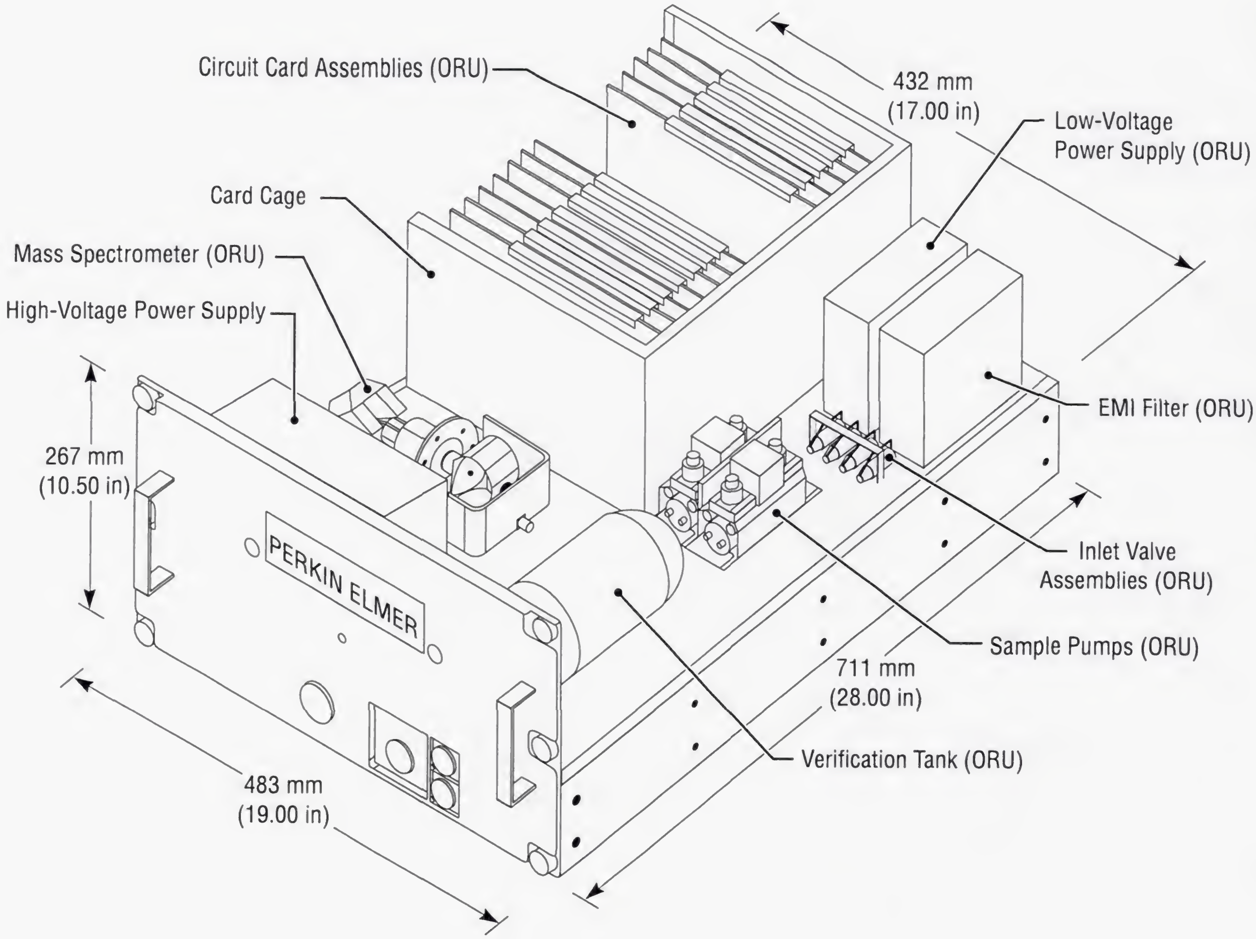


FIGURE 95.—MCA hardware.

Four ORU's are scheduled maintenance items:

- MS assembly—2 yr
- Pump assembly—2 yr
- Inlet valve assembly—10 yr
- Verification gas assembly—3 yr.

The MCA software performs the following tasks:

- Provides continuous monitoring of the major atmosphere constituents.
- Provides ppO_2 and ppN_2 results to the C&DH system (which are used by the ACS subsystem).
- Monitors the performance of the CDRA (CO_2) and TCCS (CH_4).
- Compares the calculated partial pressures with the specified allowable ranges.

The MCA sensor specifications are shown in table 28.

TABLE 28.—*MCA sensor specifications.*

Sensor	Sensor Type	Output	Power Input	Accuracy
Absolute Pressure Sensor	Strain Gauge	0 to 30 mV	10 Vdc, 2.2 mA	0.5 percent of full scale
Vacuum Sensor	Thermopile	0 to 10 mV	0.38 V ac, 21 mA	5 percent of reading
Major Constituent Composition Sensor	Single Focus Mass Spectrometer (ion current sensors, one for each constituent)	6×10^{-14} to 2×10^{-10} A, depending on the constituent	28 Vdc ±15 Vdc	1 to 5 percent of full scale, depending on the constituent

3.3.2.1.2 MCA Operation

The MCA operates by drawing a sample past the single-focusing magnetic sector MS inlet leak where gas is drawn into an ion source and the gas molecules are ionized. The ions are then accelerated by an electron field and pass into a shaped magnetic field where they are dispersed by molecular weight. The dispersed ion beams are focused into Faraday current collectors by resolving slits. The collected currents are proportional to the partial pressures. Molecules not collected are absorbed by an ion pump. Air not admitted into the MS is returned to the AR rack by a pump.

Operating modes are Initialize, Standby, Operate Autosequence, Operate Single Source, Stop, and Shutdown. The MCA power-up sequence has the following steps:

- Verify interfaces.
- Verify initialized limits.
- Verify that all readings are in the expected ranges.
- Set the state to initialize.
- Verify that the MCA is in the Standby/Override state.
- Inhibit MCA closed loop control.
- Command seven sample port valves to position A.
- Verify that the valves are in position A.
- Provide a flow path for pump 1.
- Start pump and verify operation.
- Provide a flow path for pump 2.
- Start pump and verify operation.
- Switch on the MS inlet leak heater and verify operation.
- Switch on the ion pump and verify operation.
- Switch on filament 1 and verify operation.
- Switch on filament 2 and verify operation.
- Perform verification line leak test.
- Command the MCA to perform verification.
- Command the MCA BIT.
- Command the MCA startup in autosequence state.

3.3.2.1.3 MCA Performance

The MCA range and accuracy are listed in table 29.

Table 29.—*MCA performance characteristics.*

Gas	Accuracy, % FS	Torr	Detectability, Torr	Range, Torr
N_2	2	16.0	16.0	0 to 800
O_2	2	6.0	6.0	0 to 300
H_2	5	2.5	2.5	0 to 50
CH_4	5	1.25	1.3	0 to 25
CO_2	1	0.15	0.2	0 to 15

3.3.2.1.4 Sample Delivery Subsystem (SDS)

The SDS provides the means to transport atmospheric samples from sample port locations (in every U.S. element, the JEM, the APM, and the MPLM) to the MCA, as shown in figure 96. The conditions of the samples at the interfaces between pressurized modules are listed in table 30. The atmospheric samples are returned to the atmosphere. The SDS includes three-way valves and two-way valves in the sample delivery lines. The SDS software provides the means to control the three-way distribution valves. The two-way valves are manually operated.

The sample line is made of stainless steel piping with an outer diameter of 0.32 cm (0.125 in). An adapter permits the sample line to connect with the shut-off valve fitting, which is 0.64 cm (0.25 in) in diameter. The line is held in place with stainless steel clamps.

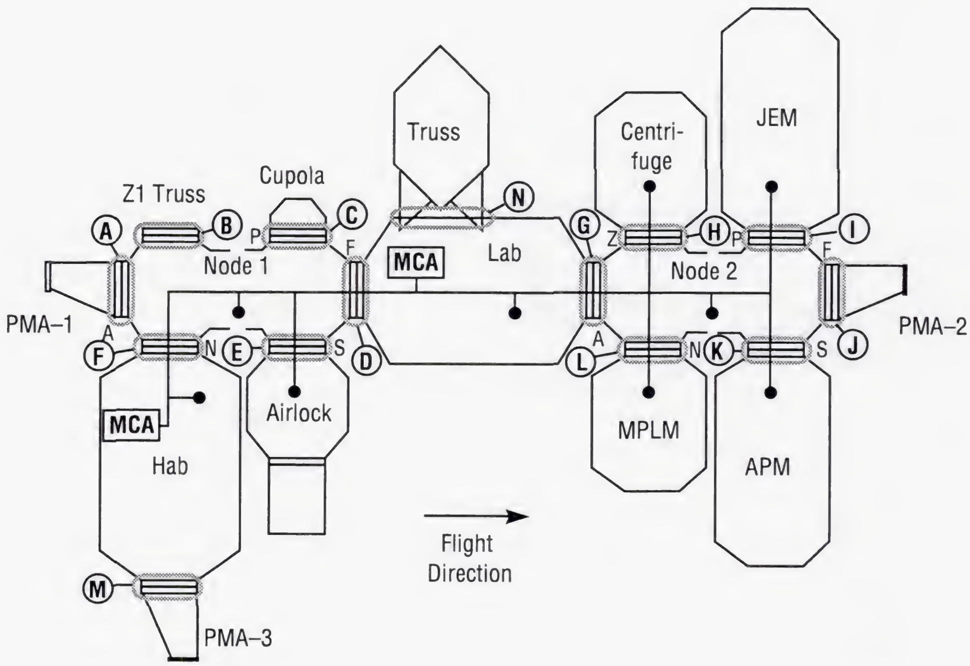


Figure 96.—Atmospheric sampling port locations.

TABLE 30.—*Atmospheric sampling interface conditions (D684–10508).*

Interface Point	ICD (SSP)	Pressure Drop		Interface Conditions Pressure During Campout		Nominal Operating Pressure		Pressure Point	Flowrate (scc/min)
		kPa	psia	kPa	psia	kPa	psia		
N1 Probe to F	41140	2.7	0.40	N/A	N/A	93.0 to 102.0	13.50 to 14.80	F	400
N1 Probe to D	41141	2.7	0.40	N/A	N/A	93.0 to 102.0	13.50 to 14.80	D	400
D to F	41140	1.7	0.25	N/A	N/A	86.8 to 102.0	12.60 to 14.80	F (all cases)	400
E to D	41141	2.7	0.40	64.8 to 67.5	9.40 to 9.80	91.6 to 100.6	13.30 to 14.60	D (from AL)	400
E to F	41140	3.4	0.50	64.1 to 66.8	9.30 to 9.70	90.9 to 99.9	13.20 to 14.50	F (from AL)	400
F to D	41141	1.7	0.25	N/A	N/A	92.0 to 100.9	13.35 to 14.65	D (from Hab)	400
F to Hab MCA	41140	1.0	0.15	N/A	N/A	N/A	N/A	N/A	400
Hab Probe to F	41140	1.7	0.25	N/A	N/A	94.0 to 103.0	13.65 to 14.95	F	400
AL to E	41145	1.4	0.20	67.5 to 70.3	9.80 to 10.20	94.4 to 103.3	13.70 to 15.00	E	400
D to Lab MCA	41141	3.8	0.55	N/A	N/A	N/A	N/A	N/A	400
Lab Probe to D	41141	4.1	0.60	N/A	N/A	91.6 to 100.6	13.30 to 14.60	D	400
G to Lab MCA	41143	2.7	0.40	N/A	N/A	N/A	N/A	N/A	400
G to D	41141	2.7	0.40	N/A	N/A	88.5 to 97.5	12.85 to 14.15	D (all cases)	400
K to G	41143	3.4	0.50	N/A	N/A	91.3 to 100.2	13.25 to 14.55	G (from APM)	400
I to G	41143	2.4	0.35	N/A	N/A	91.3 to 100.2	13.25 to 14.55	G (from JEM)	400
H to G	41143	3.0	0.43	N/A	N/A	91.8 to 103.1	13.32 to 14.97	G (from Cntr)	400
L to G	41143	3.2	0.47	N/A	N/A	91.6 to 100.8	13.33 to 14.63	L (from MPLM)	400
N2 Probe to G	41143	2.1	0.30	N/A	N/A	93.7 to 102.7	13.60 to 14.90	G	400
JEM to I	41151	1.7	0.25	N/A	N/A	94.0 to 103.0	13.65 to 14.95	I	400
MPLM to L	42007	0.7	0.10	N/A	N/A	95.1 to 104.0	13.80 to 15.10	L	400
APM to K	41150	0.7	0.10	N/A	N/A	95.1 to 104.0	13.80 to 15.10	K	400
Centrifuge to H	41147	1.0	0.15	N/A	N/A	94.7 to 103.7	13.75 to 15.05	H	400

Note: ICD—Interface Control Document

SDS features and points to remember:

- One sample line leads to the AR rack.
- The module-to-module bulkhead valves are manually operated only.
- There is one sample port per module.
- There are no sample lines to the Russian Segment.
- Sample lines support both the Hab and Lab AR racks.
- Rack location HAF5 has interface connections for a second Hab CDRA in order to support the payload CO_2 requirements.

Sample Line Shut-Off Valve

The sample line shut-off valve (shown in fig. 97) is made of stainless steel or other corrosion-resistant materials. The design allows the valve to remain open or closed without continuous power. The main characteristics of the valve are:

- Dimensions
  - 101 by 110 by 127 mm (4.0 by 4.3 by 5.0 in)
- Mass
  - 1.4 kg (3.08 lb)
- Pressure drop
  - <0.52 kPa at 600 cc/min of air at 101.3 kPa and 21.1 °C (<0.075 psid at 600 cc/min of air at 14.7 psia and 70 °F)
- Normal pressure range
  - 92.4 to 104.8 kPa (13.9 to 15.2 psia)
- Temperature range
  - 15 to 40 °C (59 to 104 °F)
- Internal leakage
  - <0.25 sccm of air at 104.8 kPa (15.2 psid)

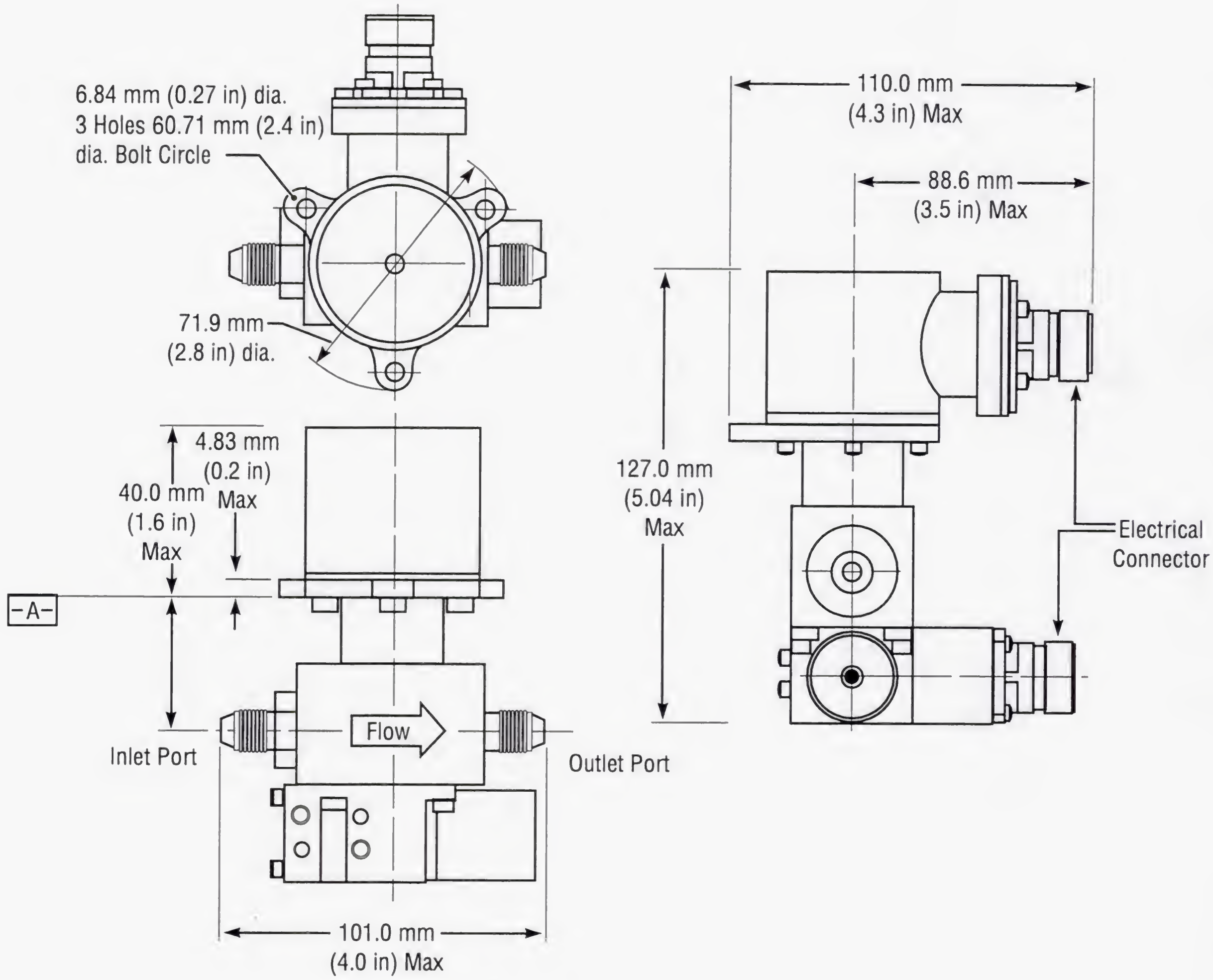


FIGURE 97.—Sample line shut-off valve.

- External Leakage
  - <2.0E–5 sccm of air at 104.8 kPa (15.2 psid)
- Power Supply
  - 28 Vdc
- Power Consumption
  - 20 W peak during activation for < 1 sec.

Sample Probe

The sample probe, shown in figure 98:

- Includes a 2 micron wire mesh filter.
- Has no electrical power system (EPS) or C&DH interfaces.
- Is mounted in the standoffs.
- Has direct access to habitat air.

Sample Line Filter

The sample line filter consists of a 2 µm absolute filter system containing a small HEPA-type cartridge and a cleanable 8 by 8 mesh screen. The cartridge life is estimated to be 1,451 days, with a 403 day cycle for cleaning the screen. A two-piece threaded assembly housing allows for maintenance of the filter. The main characteristics of the filter are:

- Dimensions
  - 33 mm diameter by 59.4 mm length (1.3 in diameter by 2.3 in length)
- Mass
  - 0.15 kg (0.33 lb)
- Pressure drop
  - 18 Pa H_2O at 600 cc/min air flowrate (0.7 in H_2O at 36.6 in^3/min air flowrate).

Filter blockage is detected by the MCA using flowrate monitoring. The ventilation system must be in operation to get a representative sample.

For samples from other modules, "jumpers" are connected through the vestibules, as shown in figure 146, 147, and 148. All manual valves are opened (only those valves which do not expose the module to vacuum) and ground control cycles the solenoid valves to assure proper function.

MDM Functions—The MDM functions are as follows:

- Control AR distribution valve:
  - This function provides control of the six AR distribution valves connected to the MDM's.
  - Activated by issuing an Open/Close command to the valves.

- Control diverter valve:
  - Provides Tier 1 access to the control valve.
  - Receives position A/B commands from the supply cabin air to AR rack function in Command and Control (C&C) MDM.
  - Provides command checking for hazardous commands and command confirmation.

- Control CO_2 bulkhead vent valve:
  - The CO_2 bulkhead vent valve is located outside of rack LAF6.
  - Activated by issuing an Open/Close command to the valve.
  - Provides Tier 1 access to the control valve.

- Control MCA isolation valve:
  - This function provides control of the MCA isolation valves in the AR rack.
  - Activated by issuing an Open/Close command to the valves.

Sampling Adapter

Before entering a module that has been sealed, a sample of the atmosphere may be collected for analysis. The External Sampling Adapter, shown in figure 99, is designed to attach to the MPEV on the vestibule side of the hatch, for this purpose. CHeCS-provided sampling equipment then attaches to the adapter. The design of the adapter allows for operation of the MPEV while the adapter is in place. The Internal Sampling Adapter, also shown in figure 99, is designed to attach to the module-side of the MPEV, for sampling the vestibule atmosphere and measuring its pressure.

3.3.2.2 Remove Gaseous Contaminants

Removal and disposal of gaseous contaminants is performed by the TCCS.

3.3.2.2.1 Trace Contaminant Control Subassembly (TCCS) Design

The TCCS hardware is shown schematically in figure 100 and consists of the ORU's listed in table 31. These ORU's are:

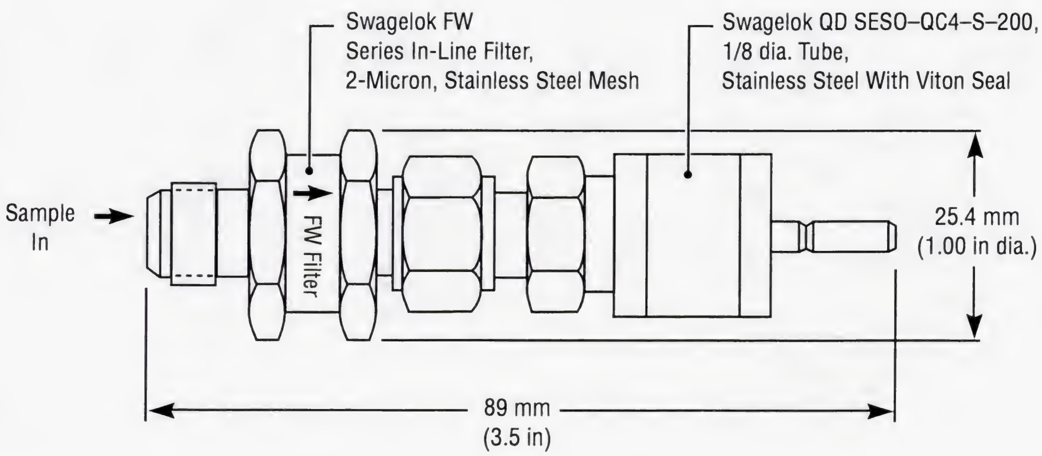


FIGURE 98.—Sample probe.

Charcoal Bed—The charcoal bed contains an expendable activated carbon for removing higher molecular weight compounds. The carbon is impregnated with phosphoric acid for ammonia removal. The charcoal bed, shown in figure 101, is replaced at 90-day intervals (or longer as determined by analysis of on-orbit contaminant concentrations).

The canister assembly, cover, and filter retainer are machined 6061–T6 aluminum and form a bolted assembly. Filters are on the inlet and the outlet sides of the canister. The inlet and outlet tubes are 2.54 cm (1.0 in) outer diameter. The O-ring seals are made of fluorocarbon. The bed contains 23 kg (50 lb) of charcoal treated with phosphoric acid.

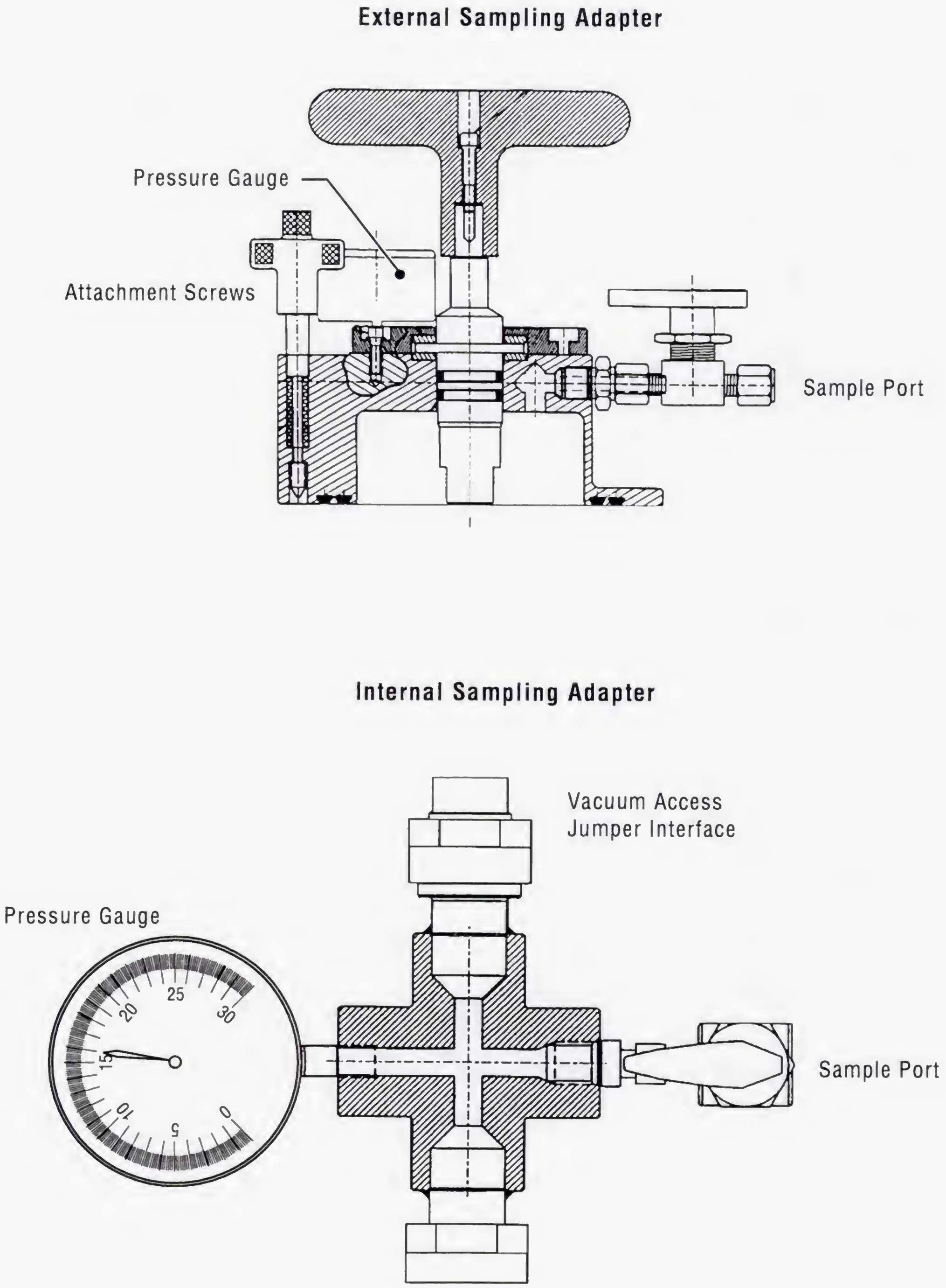


FIGURE 99.—External and Internal Sampling Adapters.

Flow Meter—The process airflow is monitored by a flow meter. The design and construction have not been determined as of this writing, but likely are similar to figure 102.

Blower—The blower controls the air flow through the TCCS. The design is similar to the blower for the 4BMS (it is a modified 4BMS blower). (See fig. 89.)

Catalytic Oxidizer—A High-Temperature Catalytic Oxidizer (HTCO), shown in figure 103, contains a paladium (Pd) on alumina catalyst to convert CO, CH_4, H_2, and other low molecular weight compounds that are not absorbed by the charcoal bed to CO_2, H_2O, or other acceptable compounds. The HTCO is scheduled to be replaced on orbit at 6-mo intervals due to catalyst poisoning predictions (the interval may be longer pending more detailed characterization of catalyst poisoning reversability). A sorbent (LiOH) bed downstream of the HTCO absorbs acidic oxidation products. The LiOH bed is replaced at 90-day intervals. This system meets U.S. 180-day SMAC's and most (if not all) Russian 360-day SMAC's at the generation rates specified in the "Prime Item Development Specification for the Lab" (document S683–29523D, table VII–A, page 111, 28 March 1995) (also, reference NASA/MSFC memo ED62(36–94)).

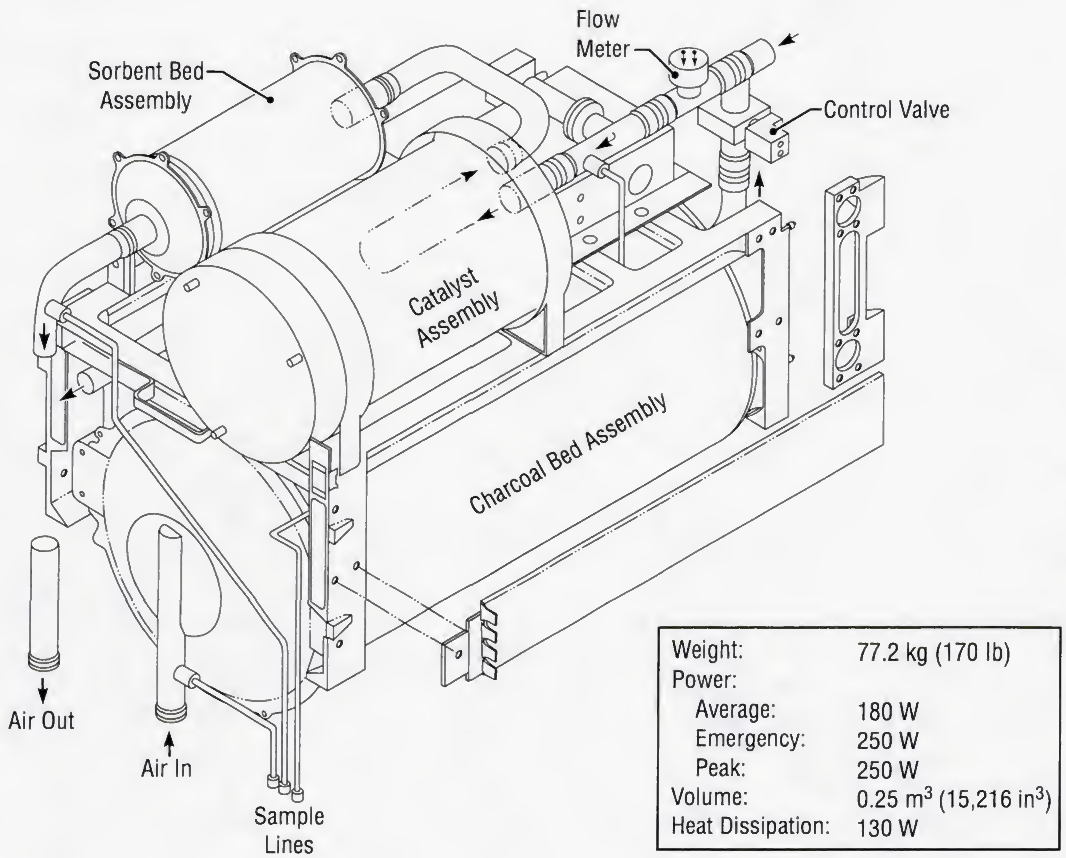
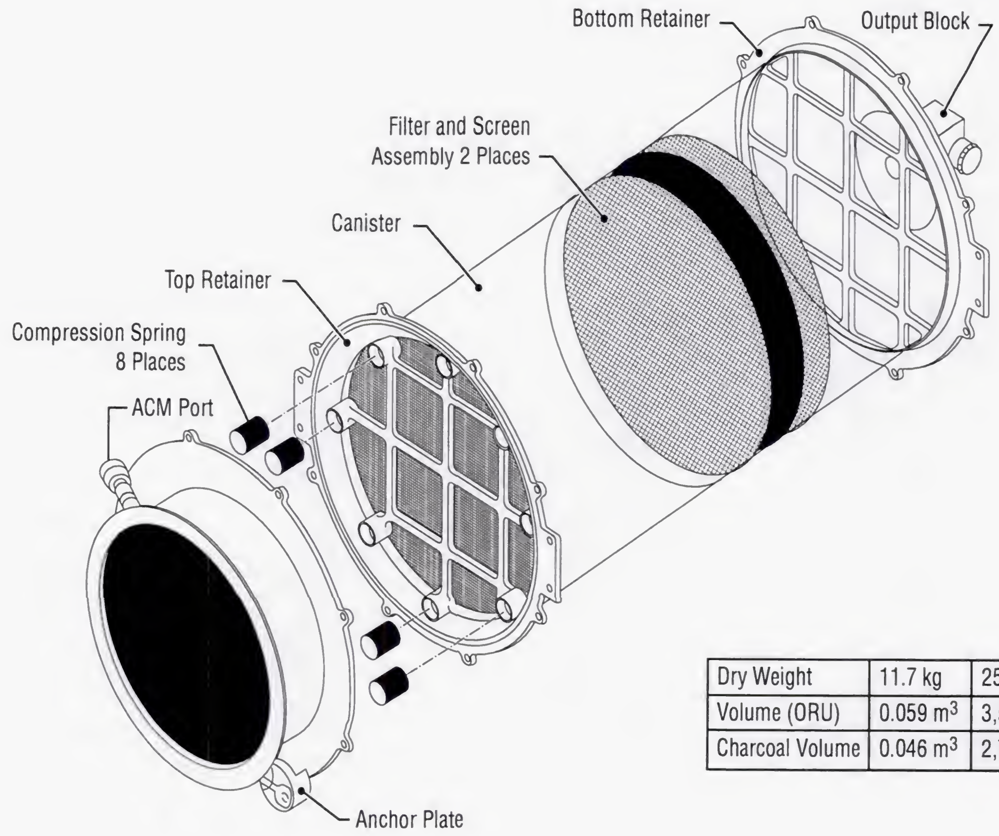


FIGURE 100.—Schematic of the TCCS hardware.



Dry Weight	11.7 kg	25.8 lb
Volume (ORU)	0.059 m^3	3,584 in^3
Charcoal Volume	0.046 m^3	2,788 in^3

FIGURE 101.—TCCS charcoal bed assembly.

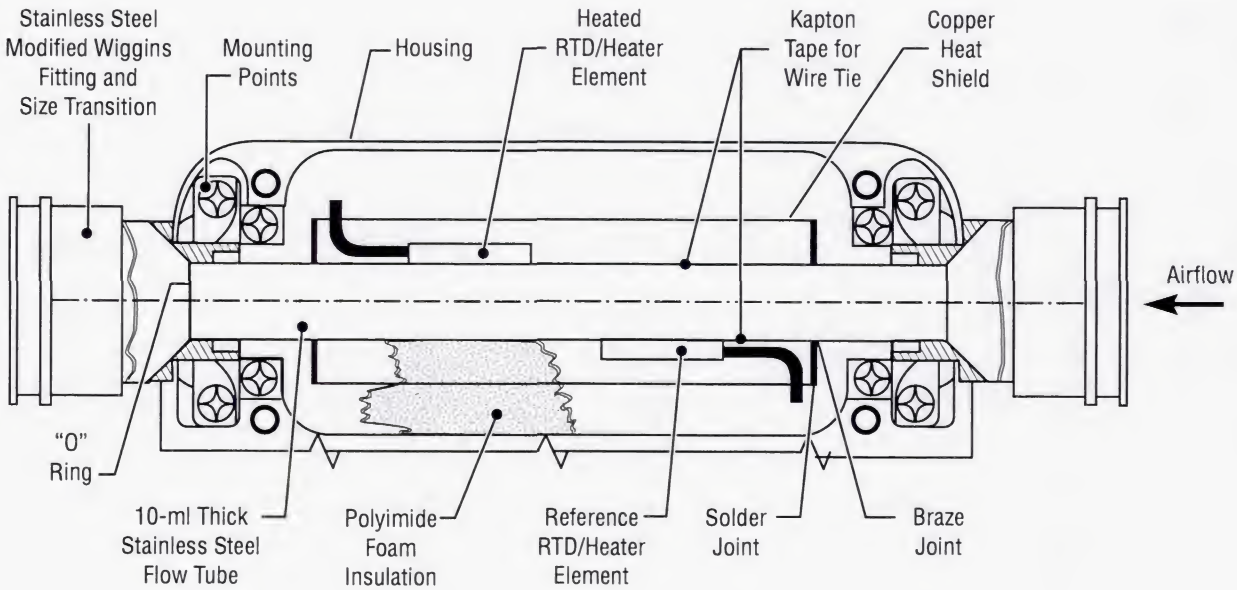


FIGURE 102.—Probable TCCS flow meter design.

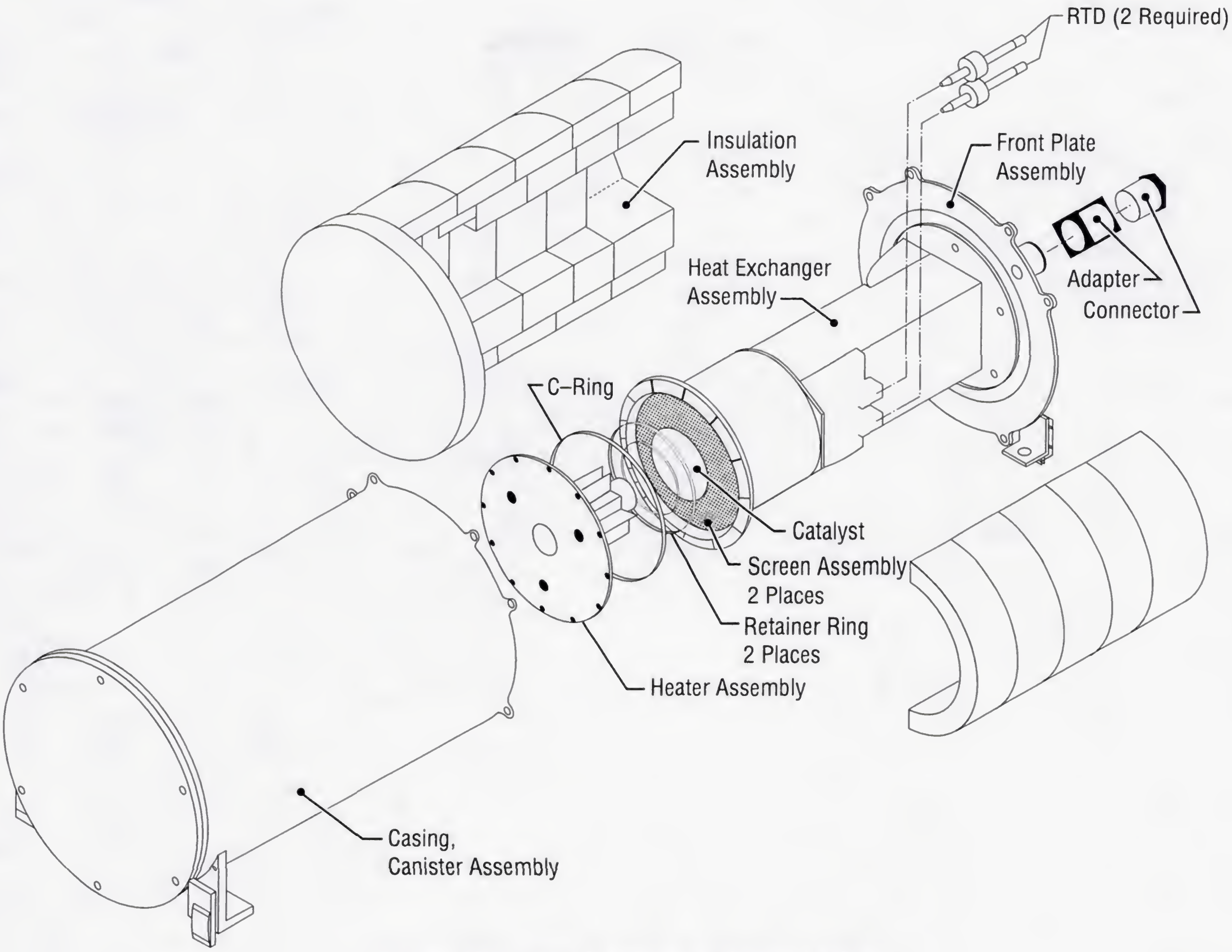


FIGURE 103.—TCCS catalytic oxidizer design.

TABLE 31.—*TCCS ORU's.*

ORU Description	Dimensions	Mass
Activated Charcoal Bed (Impregnated With Phosphoric Acid)	84 × 43 dia cm (33 × 17 dia in)	32.2 kg (71.0 lb)
Blower Assembly	15 × 15 × 15 cm (6 × 6 × 6 in)	3.0 kg (6.6 lb)
Flow Meter Assembly	15 × 7.6 × 15 cm (6 × 3 × 6 in)	0.95 kg (2.1 lb)
Catalytic Oxidizer Assembly	46 × 28 dia cm (18 × 11 dia in)	13.7 kg (30.1 lb)
LiOH Sorbent Bed Assembly	38 × 20 dia cm (15 × 8 dia in)	4.2 kg (9.2 lb)
Electronics Interface Assembly	35.6 × 18 × 7.6 cm (14 × 7 × 3 in)	4.5 kg (10.0 lb)

The catalytic oxidizer design requirements are:

- Flowrate: 70.8 L/min (2.5 scfm) (for a residence time of 0.42 sec in the catalyst bed)
- Operating temperature: 399 °C (750 °F) nominal, 538 °C (1,000 °F) maximum (used to recover catalyst conversion efficiency in the event of poisoning and degradation of contaminant conversion efficiency).
- Regenerable heat exchanger: Function—To conserve heat within the oxidizer and minimize the duty cycle of the heating element:
  - The plate/fin counter flow design has a calculated efficiency of 90 percent
- Design and construction: 0.5 kg (1.1 lb) catalyst (Pd on 0.32 cm (1/8 in) alumina pellets):
  - Two platinum wire heaters
  - Two 50 ohm platinum wire, Inconel™ 600 sheath, RTD's.

The mass is 10.1 kg (22.3 lb), the ORU volume is 0.019 m^3 (1,138 in^3), and the catalyst volume is 0.49 L (30 in^3).

Sorbent (LiOH) Bed—The LiOH bed, shown in figure 104, removes the undesirable acidic byproducts of catalytic oxidation such as HCl, Cl_2, F_2, NO_2, and SO_2. The flowrate is 70.8 L/min (2.5 scfm). The bed contains 1.4 kg (3.0 lb) of LiOH. Most of the bed components are made of 321/347 stainless steel. The filter assembly is made of 316L stainless steel wire screen with polypropylene mesh filters. Other metal components are made of corrosion-resistant materials, and the O-rings are made of fluorocarbon. The mass is 2.8 kg (6.1 lb), the ORU volume is 0.004 m^3 (245 in^3), and the sorbent volume is 2.8 L (170 in^3).

3.3.2.2.2 TCCS Operation

The habitat atmosphere flows through the charcoal bed first, to remove high molecular weight contaminants. A blower and flow meter downstream of the charcoal bed control the air flowrate to maintain 4.2 L/sec (9.0 scfm). Next, a portion of the air flows through the high temperature (399 °C, 673 K, 750 °F) catalytic oxidizer to remove low molecular weight contaminants such as CH_4, H_2, and CO. Then, the air enters a LiOH bed to remove any acidic byproducts generated in the oxidation process, before returning to the atmosphere via the THC return duct. The regenerable HX conserves heat within the oxidizer and minimizes the heating element duty cycle.

The TCCS operating states and transition commands are shown in figure 105. The TCCS has five states of operation:

- Off—Hardware is unpowered, ready to initialize.
- Standby—Software is initialized and power is enabled to the sensors, heater is off.
- Warmup—Brings the heater up to operational temperature; may require 6 to 8 hr to bring up a cold unit.
- Full Up—The unit is placed in this state when the warmup process is successfully completed; the heater and blower are both active.
- Heater Override—Power to the heater is switched off but air continues to flow through the assembly.

The TCCS operates primarily in two configurations: full-up and heater override. During full-up operation, both the front half (the charcoal bed) and the back half (catalytic oxidizer and sorbent bed) are functioning. During heater override process air continues to flow through the TCCS, but the catalytic oxidizer is maintained at ambient temperature. When unpowered, the TCCS is in the Off state. Upon receiving an Initialize command, power is activated to the TCCS circuits and the TCCS is placed in the Standby state. From Standby the TCCS can be commanded to operate Full Up, Heater Override, or Shutdown. To operate full up, airflow is activated and monitored and the catalytic oxidizer is activated. The system is then in the Warmup state. In the Heater Override state, airflow is activated and monitored but the catalytic oxidizer is not activated. For Shutdown, power is deactivated within the TCCS.

Power up sequence: within the AR subsystem the MCA and SDS are activated first, then the CDRA, and finally the TCCS. The MCA and SDS are first in order to begin sampling the atmosphere major constituents as soon as possible.

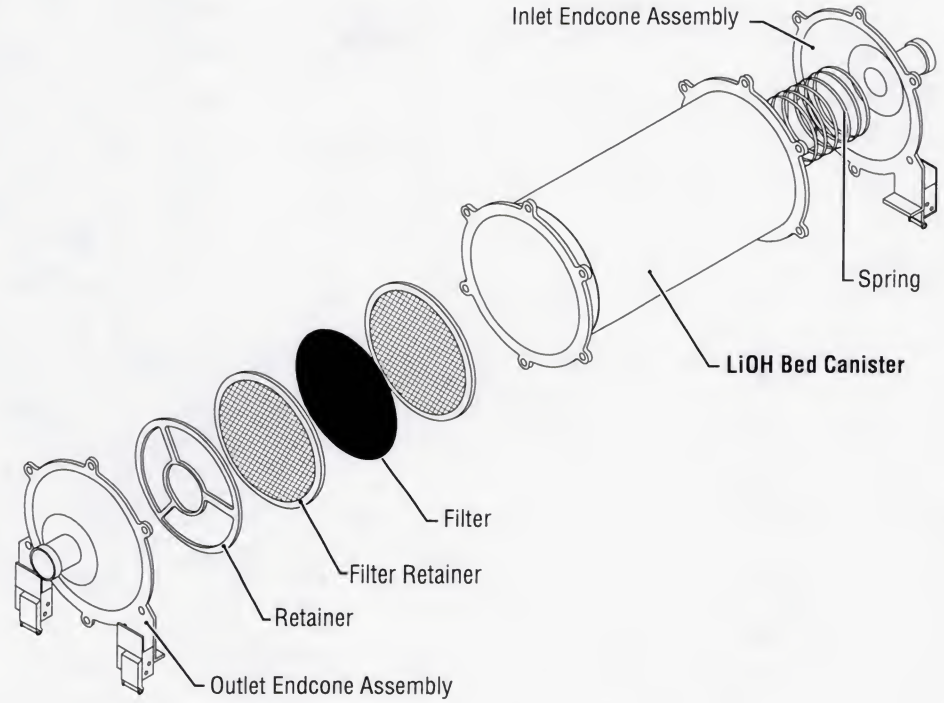


Figure 104.—TCCS LiOH bed assembly.

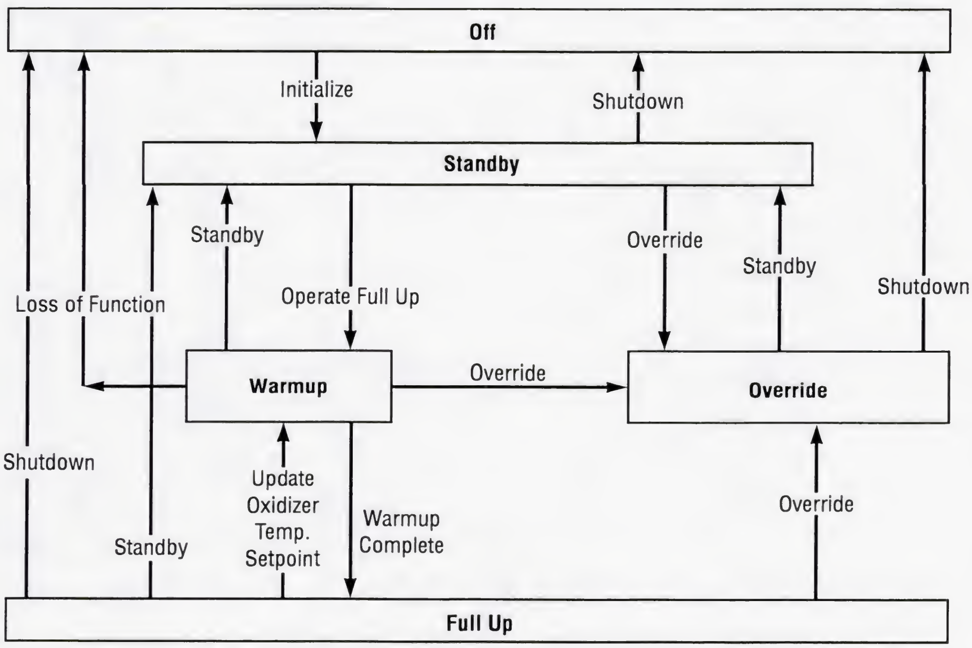


Figure 105.—TCCS operating states and transition commands.

The TCCS power up sequence:

- Verify interfaces
- Verify initialized limits
- Verify that all readings are in the expected ranges
- Set the state to Initialize
- Verify that the TCCS is in the Standby/Override state
- Inhibit TCCS closed loop control
- Provide a flow path for the blower
- Start the blower and verify operation
- Start the heater and verify operation
- Command the TCCS BIT
- Command the TCCS startup.

The TCCS process is shown in figure 106. The TCCS maintains the concentration of contaminants in the module atmosphere within acceptable limits by:

- Absorbing high molecular weight contaminants and ammonia.
- Controlling the necessary process airflow.
- Oxidizing low molecular weight hydrocarbons and CO.
- Protecting the catalyst from poisoning.
- Chemically absorbing toxic byproducts of catalytic oxidation.

Software controllers are used to:

- Control the trace contaminant removal process.
- Determine the status of the trace contaminant removal equipment.
- Detect loss or degradation of the trace contaminant control functionality.

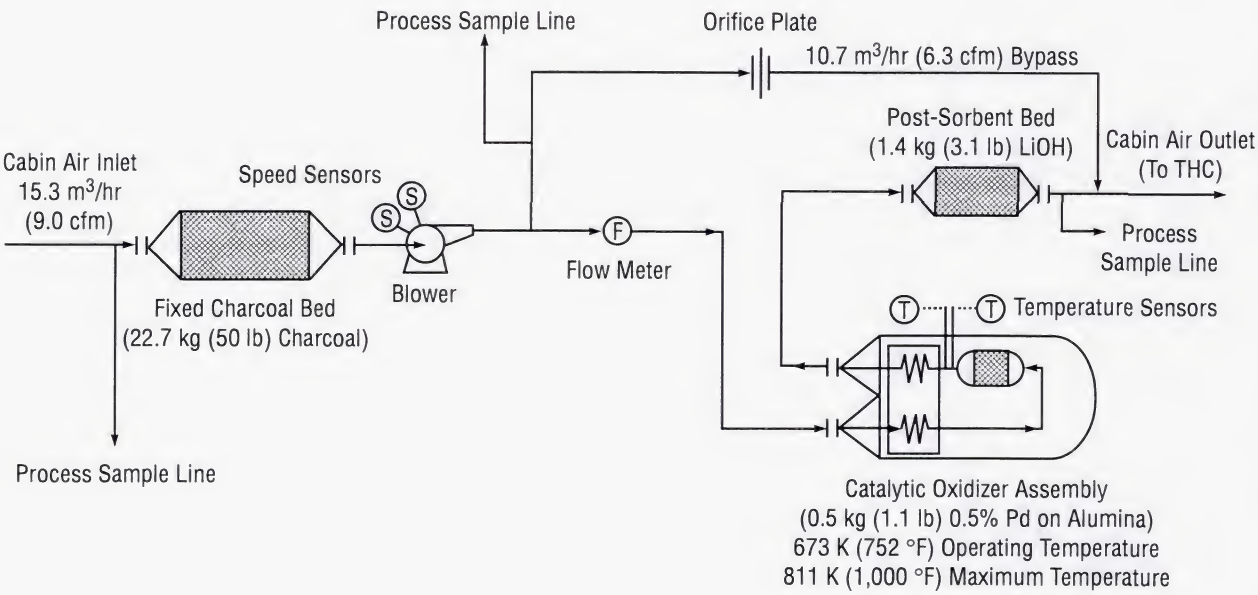


FIGURE 106.—TCCS process diagram.

Scheduled maintenance of the TCCS involves three ORU's:

- The charcoal bed assembly, replaced every 90 days or longer, depending on the contaminant load
- The LiOH bed assembly, replaced every 90 days or longer, depending on the contaminant load
- The catalytic oxidizer assembly replaced once each year.

3.3.2.2.3 TCCS Performance

The allowable concentrations of contaminants are listed in table 32. (A more thorough list, including generation rates, is in "Control Internal CO_2 and Contaminants Capability Description Document," D684–10216–01, Boeing.)

TABLE 32.—Maximum allowable concentrations of atmospheric contaminants.

Chemical		Potential Exposure Period 1 hr	24 hr	7 days	30 days	180 days
Acetaldehyde	mg/m^3	20	10	4	4	4
Acrolein	mg/m^3	0.2	0.08	0.03	0.03	0.03
Ammonia	mg/m^3	20	14	7	7	7
Carbon Dioxide	mmHg	10	10	5.3	5.3	5.3
Carbon Monoxide	mg/m^3	60	20	10	10	10
1.2-Dichloroethane	mg/m^3	2	2	2	2	1
2-Ethoxyethanol	mg/m^3	40	40	3	2	0.3
Formaldehyde	mg/m^3	0.5	0.12	0.05	0.05	0.05
Freon 113	mg/m^3	400	400	400	400	400
Hydrazine	mg/m^3	5	0.4	0.05	0.03	0.005
Hydrogen	mg/m^3	340	340	340	340	340
Indole	mg/m^3	5	1.5	0.25	0.25	0.25
Mercury	mg/m^3	0.1	0.02	0.01	0.01	0.01
Methane	mg/m^3	3,800	3,800	3,800	3,800	3,800
Methanol	mg/m^3	40	13	9	9	9
Methyl ethyl ketone	mg/m^3	150	150	30	30	30
Methyl hydrazine	mg/m^3	0.004	0.004	0.004	0.004	0.004
Dichloromethane	mg/m^3	350	120	50	20	10
Octamethyltrisiloxane	mg/m^3	4,000	2,000	1,000	200	40
2-Propanol	mg/m^3	1,000	240	150	150	150
Toluene	mg/m^3	60	60	60	60	60
Trichloroethylene	mg/m^3	270	60	50	20	10
Trimethysilanol	mg/m^3	600	70	40	40	40
Xylene	mg/m^3	430	430	220	220	220

3.3.2.3 Dispose of Gaseous Contaminants

Sorbent materials in the TCCS are replaced periodically (as described above) and the used materials are discarded.

3.4 Fire Detection and Suppression (FDS)

The means to detect, isolate, and extinguish fires must be present in all locations where this capability may be needed. The FDS equipment is located in each module containing powered racks, as indicated in figure 107 through 113.

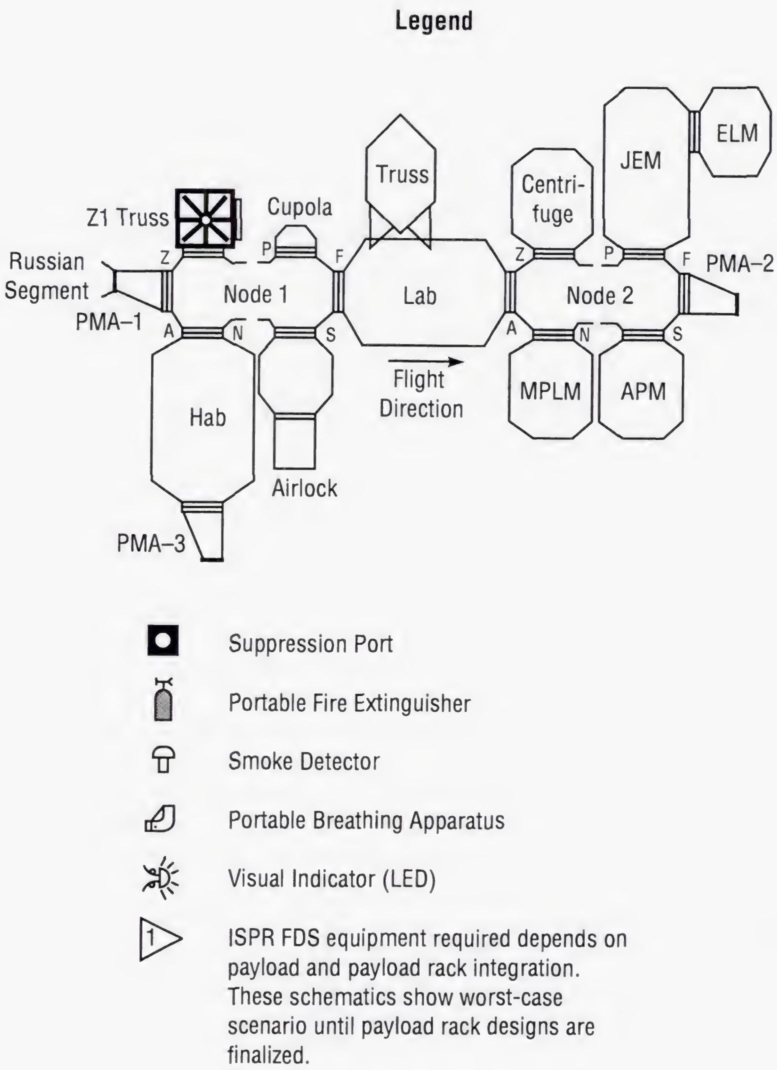


FIGURE 107.—FDS subsystem.

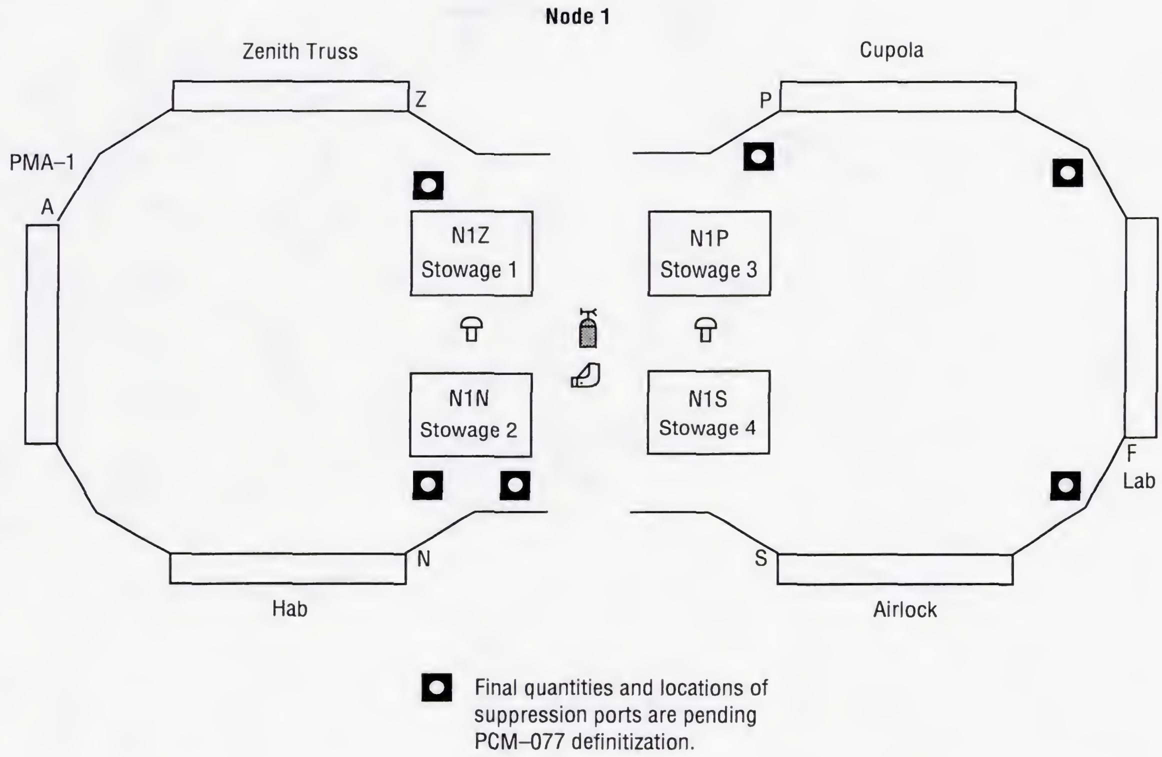


FIGURE 108.—FDS subsystem (continued).

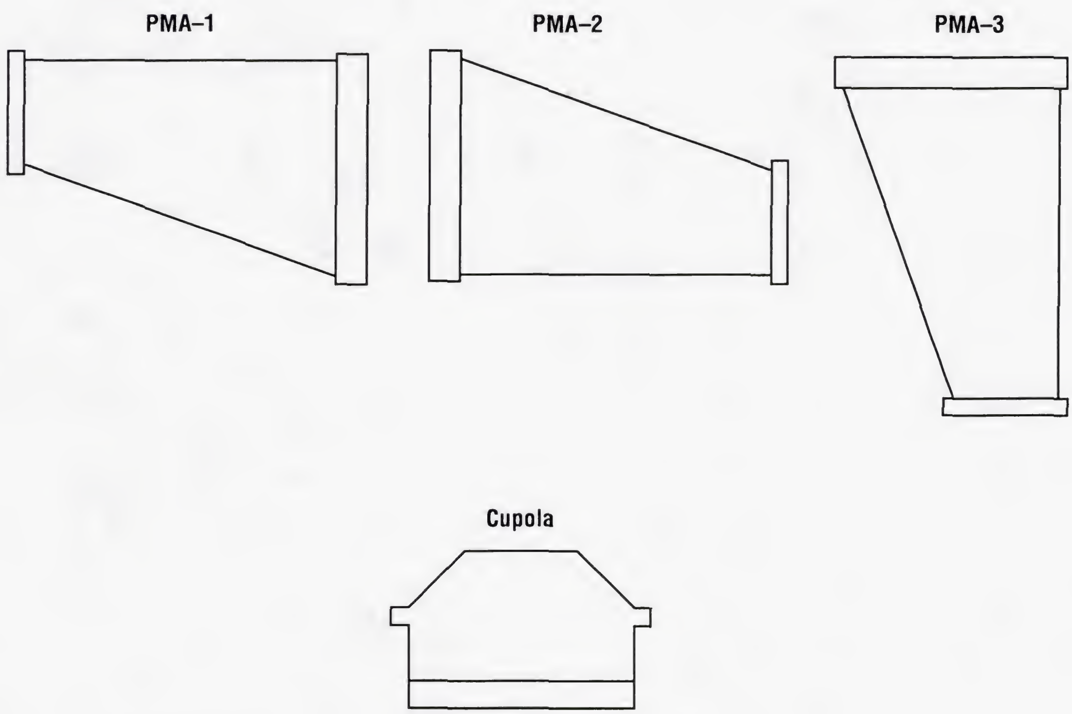


FIGURE 109.—FDS subsystem (continued).

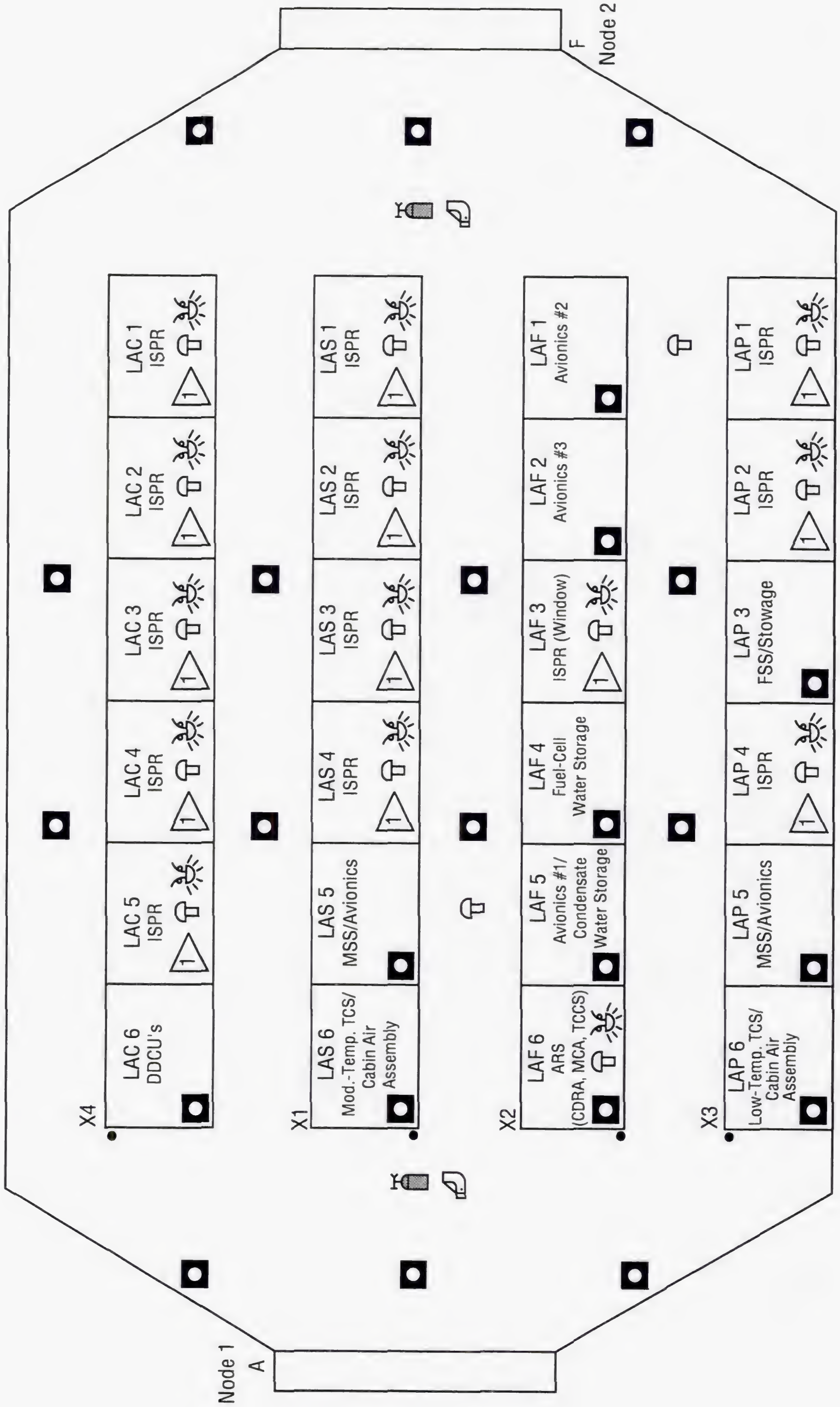


FIGURE 110.—FDS subsystem (continued).

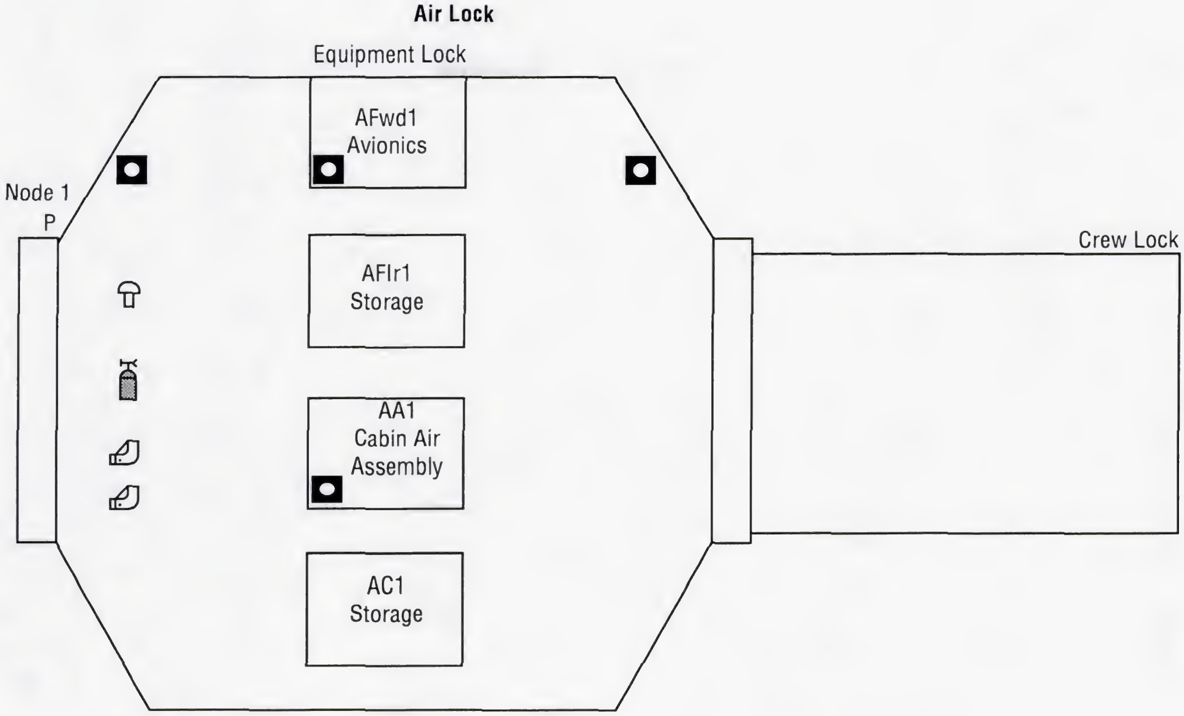


FIGURE 111.—FDS subsystem (continued).

3.4.1 Respond to Fire

Ventilation in equipment and experiment racks provides some cooling but is primarily required for fire detection. Circulation fans are in all racks requiring smoke detectors so that an incipient fire can be quickly detected and located.

An AAA (circulation fan with an HX, see section 3.2.1.3) is required in the following racks:

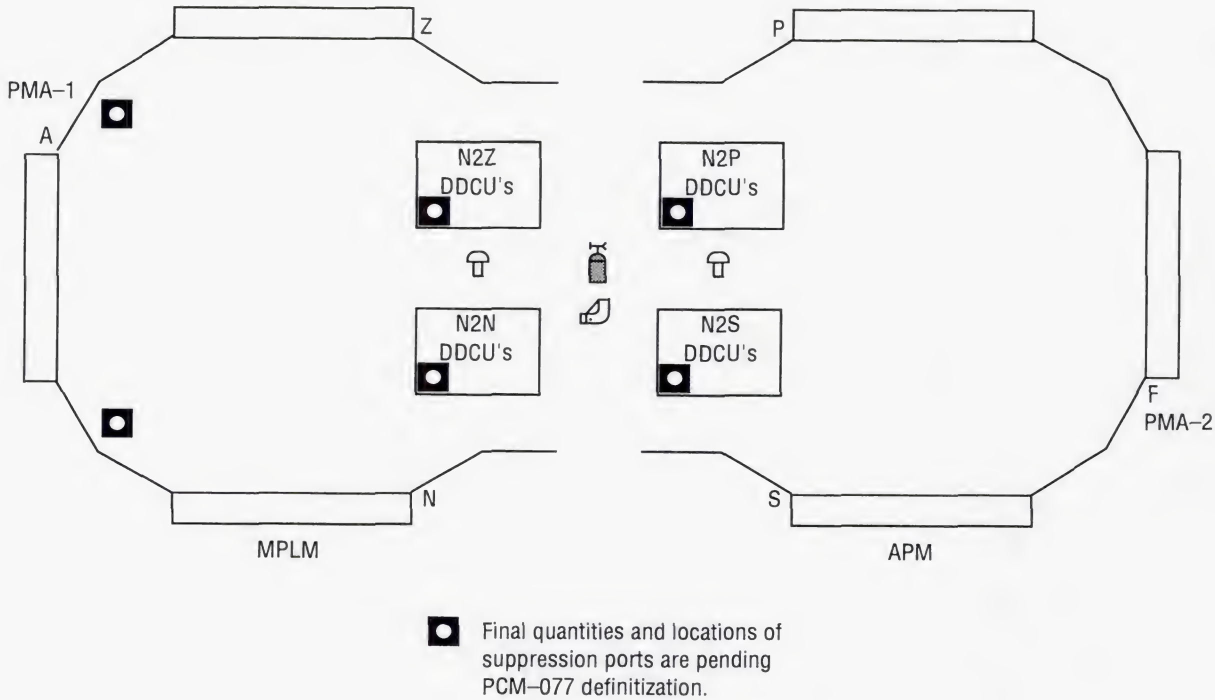
- LAF6—ARS rack
- Lab ISPR's (optional) LAC1–5, LAS1–4, LAP1–4
- HAC4—CHeCS EHS/HMF rack (at Flight 6A this rack is located at LAF4, where the fuel-cell water storage racks are later located)
- HAC5—CHeCS EHS rack
- HAF3—Water processor
- HAF4—Urine processor
- HAF5—ARS rack
- HAF6—ARS rack
- HAP1—Wardroom.

Racks with detectors have red LED's that blink when the detector is activated. When a fire is detected an audible alarm is sounded and the C&W panel (shown in fig. 114) indicates the presence of a fire. The immediate crew response is to don PBA's and to read the messages on the laptop computers that identify the sensors activated. If the crew detects a fire before the automated system, a "Fire" button on the C&W panel allows the crew to activate the alarm.

The automated response to a fire depends upon whether a rack sensor or a cabin sensor is activated, or whether a crew member initiated the alarm. When a rack sensor is activated, the response is to:

- Remove power to the rack (except to the LED) in order to isolate ignition sources and stop internal airflow.
- Stop air exchange between the affected module and adjacent modules.
- Perform further actions as necessary by the crew and ground controllers to extinguish the fire.

Node 2



Centrifuge

TBD

FIGURE 112.—FDS subsystem (continued).

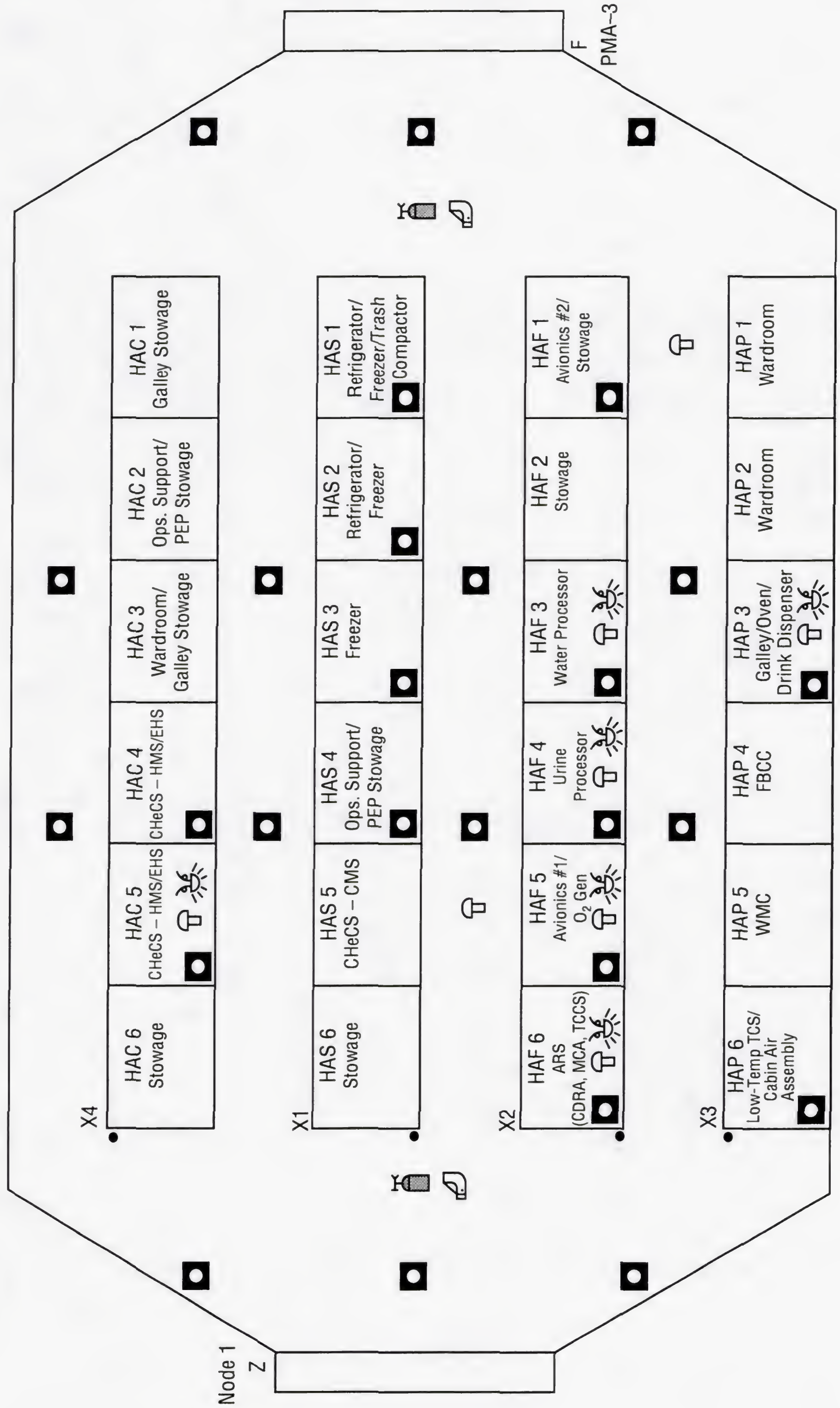


FIGURE 113.—FDS subsystem (continued).

When a cabin sensor is activated, the response is to:

- Stop cabin airflow within the element.
- Stop air exchange between the affected module and adjacent modules. For Node 1, the aft IMV valves are commanded closed.
- Stop all O_2/N_2 introduction into the cabin.
- Perform further actions as necessary by the crew and ground controllers to locate, isolate, and extinguish the fire.

When a crew member initiates an alarm, the response is to:

- Close all IMV valves and switch off all IMV fans.
- Stop cabin airflow within the modules.
- Switch the CDRA to Standby.
- Stop all O_2/N_2 introduction into the cabin.
- Switch the MCA to Standby.
- Perform further actions by the crew and ground controllers to locate, isolate, and extinguish the fire.

Module depressurization is not an automated response and can only be initiated by the crew or Ground Control.

3.4.1.1 Detect a Fire Event

Fire is detected by smoke detectors in the racks with internal airflow, smoke detectors at the ventilation return air ducts, and by the crew's sense of smell or other senses. No single failure can cause loss of the capability to detect fires where such loss of functionality may create a catastrophic hazard.

Smoke detectors monitor the Lab atmosphere for the presence of smoke or other combustion particles. Upon sensing smoke a detector sends a signal to the command and control processor. Also, the crew can manually initiate fire event notification. A Class I alarm is activated that visually indicates the fire's location.

The smoke detectors, shown in figure 115, are 17.5 by 17.8 by 14.6 cm (6.9 by 7.0 by 5.75 in), have a mass of 1.41 kg (3.11 lb), and use 1.48 W continuous operating power.

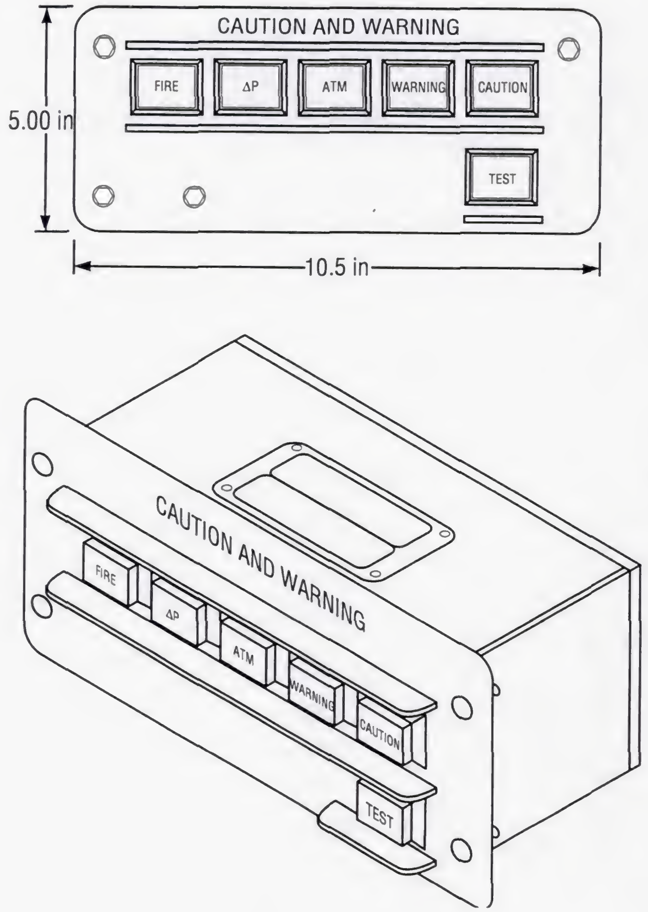


FIGURE 114.—USOS C&W panel.

3.4.1.2 Isolate Fire Control Zone

Measures are taken to isolate the fire within 30 sec to keep it from spreading. This is done by switching off power and ventilation to the affected location. Inter-module ventilation is also switched off within 30 sec after activating a Class I fire alarm.

3.4.1.3 Extinguish Fire

At each potential fire source location the means for applying a fire suppressant is provided via a port (shown in fig.116), so that any fire can be suppressed within 1 min of detection. When necessary to depressurize a module, the atmosphere can be vented through a vent valve to achieve an oxygen concentration of <3.4 kPa (1.0 psia) within 10 min.

PFE's, shown in figure 117, are 47.8 cm (18.8 in) in height by 35.0 cm (13.8 in) in diameter and have a mass of 5.35 kg (11.8 lb). The PFE's are manually activated

and each contain 2.7 kg (6 lb) of CO_2 at 5.86 MPa (at 22 °C) (850 psia (at 72 °F)) and are certified for use on Class A, B, and C type fires. The PFE's are equipped with a cone nozzle for open cabin use or to attach to the ISPR fire ports. To suppress a fire in a rack, a PFE is connected to the rack face by breaking the plastic seal over the fire port and directing suppressant into the rack. The O_2 concentration in an enclosed fire protection location is reduced to < 10.5 percent within 1 min of suppressant discharge. When CO_2 is discharged, the PFE becomes extremely cold. The bottle temperature drops to –18 °C (0 °F) and the nozzle temperature drops to –34 °C (–32 °F). The handle remains within allowable touch temperature limits.

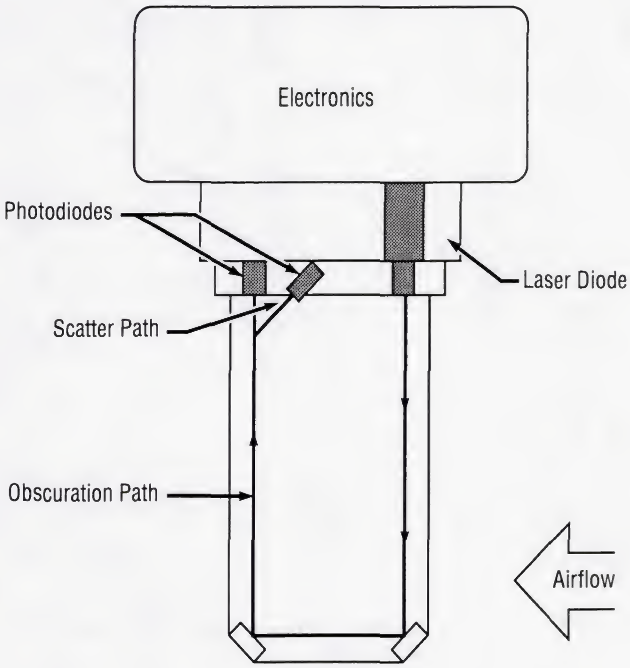


FIGURE 115.—Smoke detector.

3.4.1.4 Recover From a Fire

The CO_2 discharged from a PFE is removed from the atmosphere by the CDRA. If a module is depressurized to extinguish a fire or to remove contaminants from the atmosphere, the capability is present to repressurize the module to restore the habitable environment.

3.5 Waste Management (WM)

The WM equipment is located in the Hab and consists of the commode and urinal, shown schematically in figures 118 and 119.

3.5.1 Accommodate Crew Hygiene and Wastes

The commode operates by pulling cabin air through the commode seat to draw feces into the waste canister. The blower is activated when the seat lid is lifted and operates for about 30 sec after the lid is closed. A replaceable plastic fecal collection bag covers the opening to the waste canister and holds the feces. After use, the bag is sealed with a plastic lid and is compressed into the waste canister by a piston. The piston is moved into position over the canister to compact the fecal collection bags. Each canister is sized to hold about 28 defecations and a signal notifies the crew when full. When removing a canister, a filter lid is placed on it and the canister is stored for return to Earth. The canister may be cleaned for reuse.

The urine collector consists of a funnel with cabin airflow directing the urine into the funnel. Each crew member has his or her own replaceable funnel. To stabilize the urine for processing (e.g., to prevent urea from forming ammonia) each liter of urine is pretreated with at least 5.00 g Oxone® and about 2.30 g sulfuric acid (H_2SO_4) before being delivered to the urine processor. The maximum level of acid is 3.65 g/L of urine, including 1.33 g/L of potassium bisulfate ($KHSO_4$) that is needed to form the H_2SO_4 into solid tablets. The Oxone® is also in the form of solid tablets. These tablets are then packaged in "strings" that are about 15.2 cm (6 in) long, as shown in figure 120, with Gore-Tex® covering and Teflon™ lacing. With a debris filter attached to the string, the length is 25.4 cm (10 in). One string is placed in the urine inlet line, as shown in figure 119. For a crew of four people, the string is replaced twice each day. For long-term storage, the strings are packaged to prevent moisture intrusion.

3.6 Water Recovery and Management (WRM)

WRM services available in the Lab at Flight 6A are limited to condensate collection, storage, and venting. The capability to add water processing to the Lab is included, but until the Hab is operational at Flight 19A, the Russian Service Module provides potable water for U.S./international astronauts when the space shuttle is not docked to the *ISS*. Potable water is also provided by the space shuttle, which produces excess water from fuel cells.

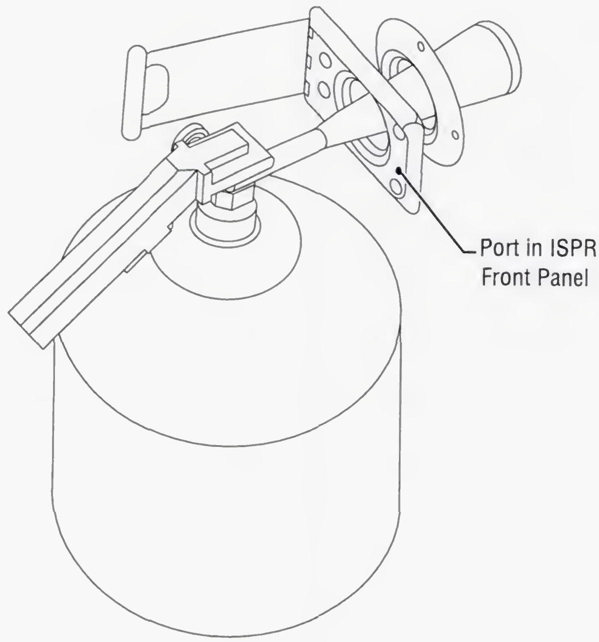


FIGURE 116.—Fire suppression port (in an ISPR front).

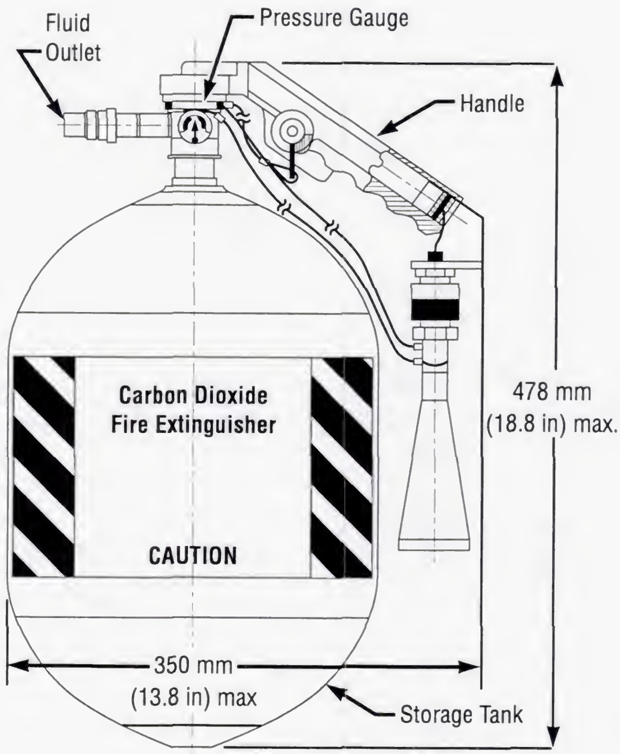


FIGURE 117.—PFE (D683–15006–1, rev.A).

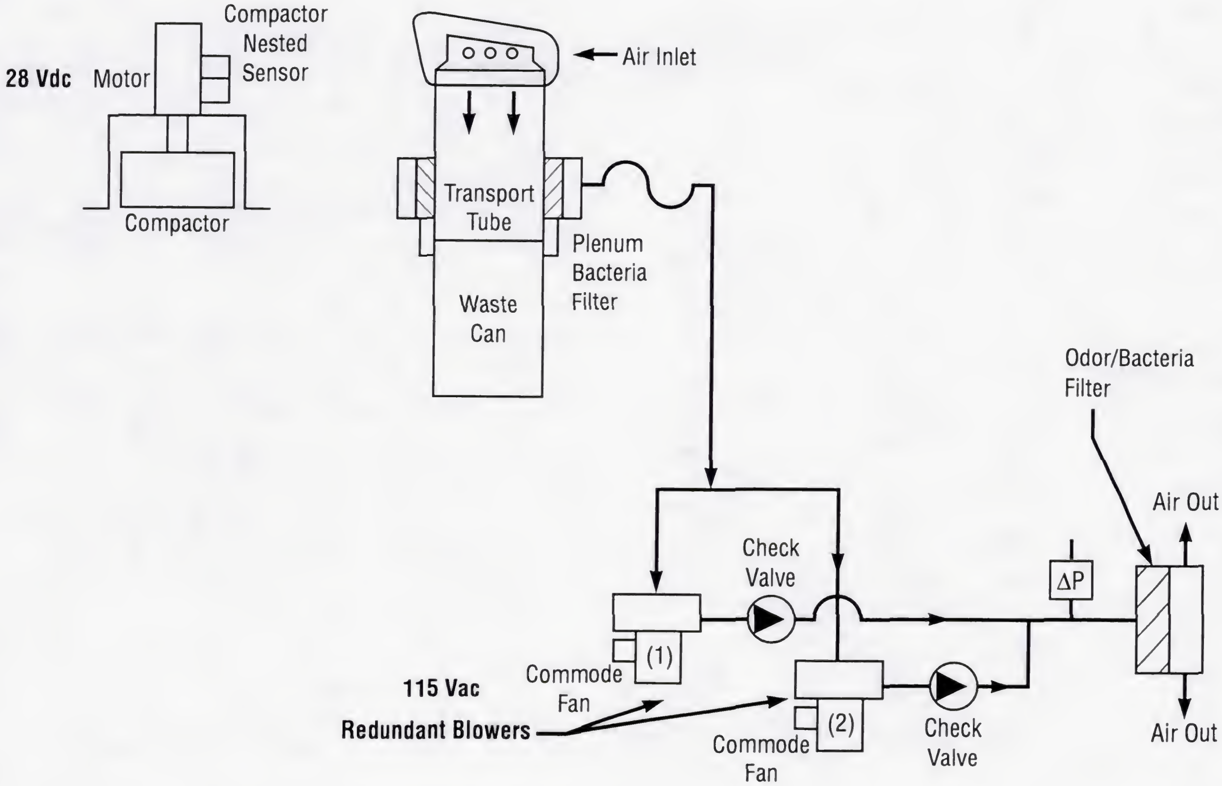


FIGURE 118.—USOS WM commode schematic.

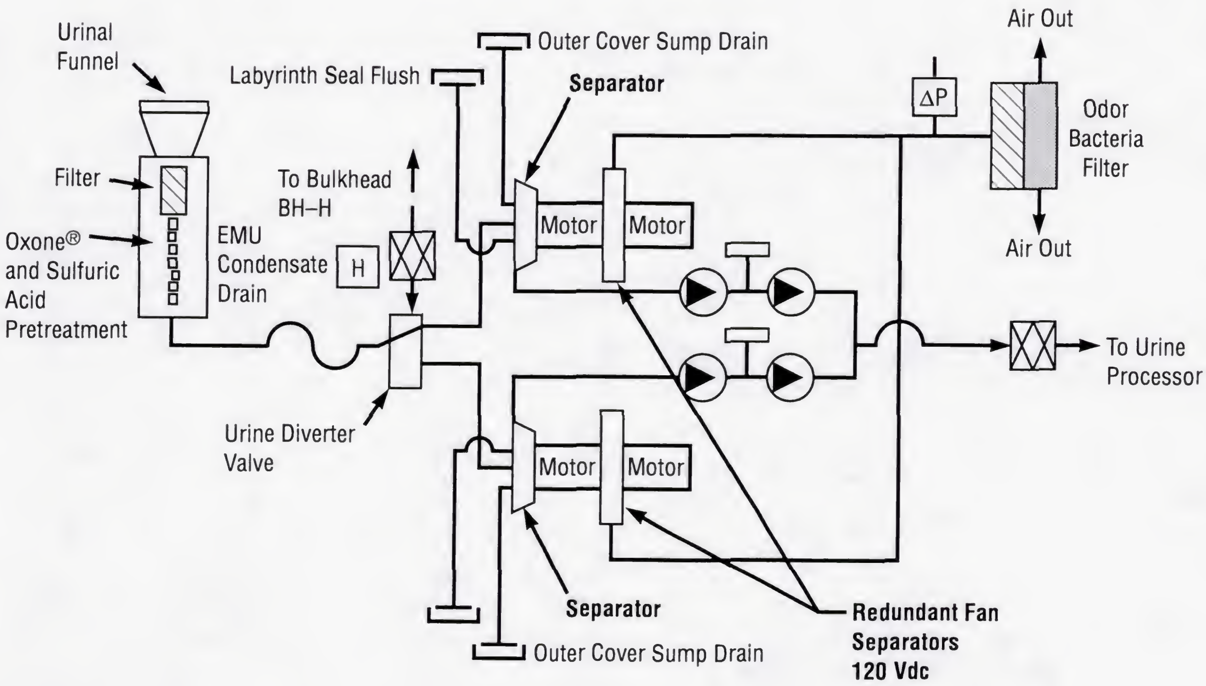


FIGURE 119.—USOS WM urinal schematic.

The WRM subsystem external interfaces are shown in figure 121. The WRM subsystem, shown schematically in figure 122, distributes potable water for crew use and for payloads, and collects wastewater for processing. The WRM equipment is located in the Hab, but wastewater is collected from and processed water is delivered to other modules, as shown in figures 123 through 129.

The WRM services in the Hab after Flight 19A are:

- Water quality monitoring
- Potable water supply
- Hygiene water supply
- Wastewater processing
- Urine processing.

3.6.1 Provide Water for Crew Use

Potable quality water is provided for crew consumption and hygiene purposes. The WRM subsystem processes wastewater into potable water. To ensure that the water is of acceptable quality, the composition of processed water is monitored as described below. Prior to installation of the Hab, the wastewater consists of condensate from the THC subsystem and EMU wastewater. This water is stored in the condensate storage assembly and vented overboard periodically or is manually transferred to the RS for processing.

After the Hab is installed, wastewater also includes hygiene return water (oral hygiene water, and handwash water) and pretreated urine (from the WM subsystem). Additional sources include CHeCS waste, animal condensate, and wet-shave water. The WRM subsystem also provides storage and distribution of potable, waste, and fuel-cell water; and vents to space excess wastewater that cannot be processed or used by the *ISS*. These features and capabilities are described below.

The major assemblies and ORU's of the WRM are:

- Wastewater vent assembly
- Condensate storage assembly
- Fuel-cell water storage tanks
- Water distribution network
- Water Processor (WP)
- Process Control and Water Quality Monitor (PCWQM)
- Urine Processor Assembly (UPA)
- Contingency water collection bags (for manual storage and transfer of water).

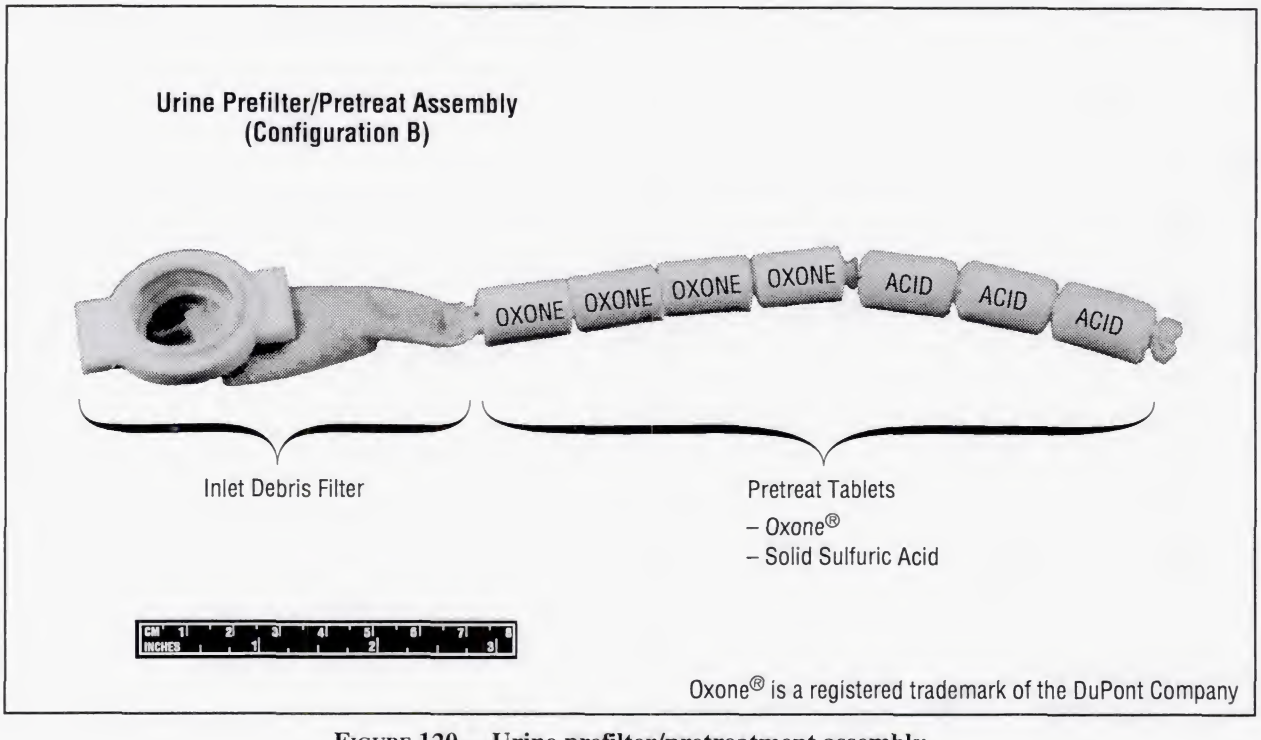


FIGURE 120.—Urine prefilter/pretreatment assembly.

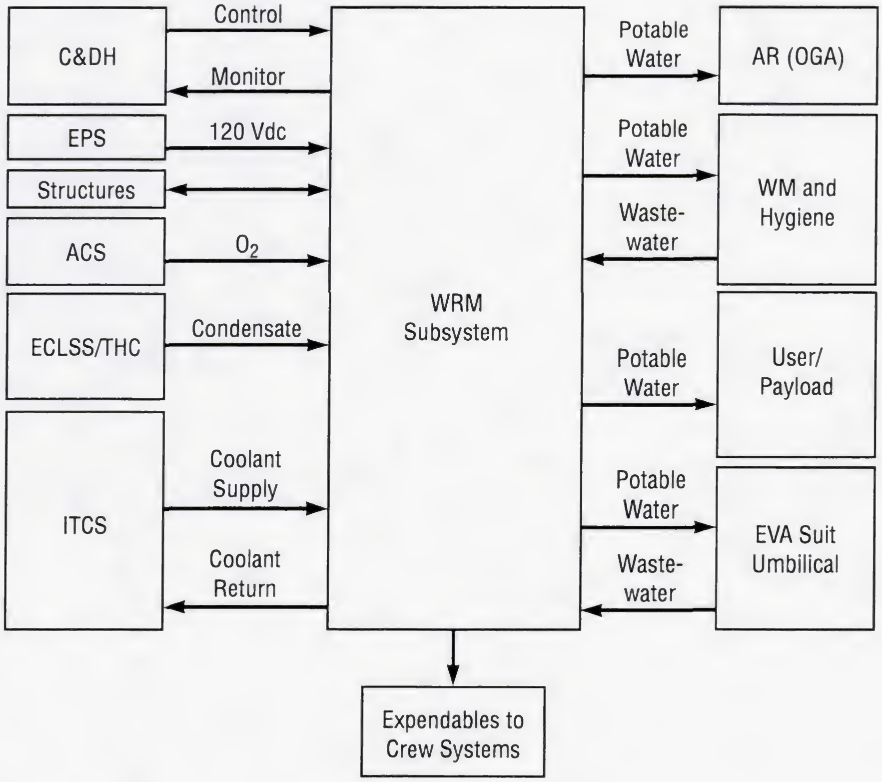


FIGURE 121.—WRM subsystem interfaces.

3.6.1.1 Wastewater Vent Assembly

The wastewater vent assembly provides controlled, non-propulsive venting of wastewater from the *ISS*. Venting may be initiated manually or automatically via computer control. Two vent assemblies, shown in figure 130, each consist of two solenoid valves in series, a particulate filter, a dump nozzle, and a heater jacket assembly. The vent assemblies are located in the forward end of the Lab, 180 degrees apart, as shown in figure 131. The vent assemblies are EVA maintainable, designed to prevent freezing and clogging, comply with contamination requirements, and minimize fluid dynamics. The wastewater vent assemblies consist of:

- Two-way solenoid valves (two for each assembly) mounted in series to control venting operations and isolate the internal atmosphere from the external environment when not venting. These are replaceable from inside the Lab module.
- Nozzle heater (one for each assembly) to heat the nozzle during pre-heat, venting, and post-heat operations. This is replaceable from outside the Lab module.
- Heater jacket (one for each assembly) to support heating the nozzle during pre-heat, venting, and post-heat operations. This is replaceable from outside the Lab module.
- Plumbing and orifice made of 1.27 cm (0.5 in) diameter titanium tubing. The orifice is sharp-edged.
- Particulate filter (1 for each assembly) made of titanium mesh to remove particles as small as 100 microns. This is replaceable from inside the Lab module.

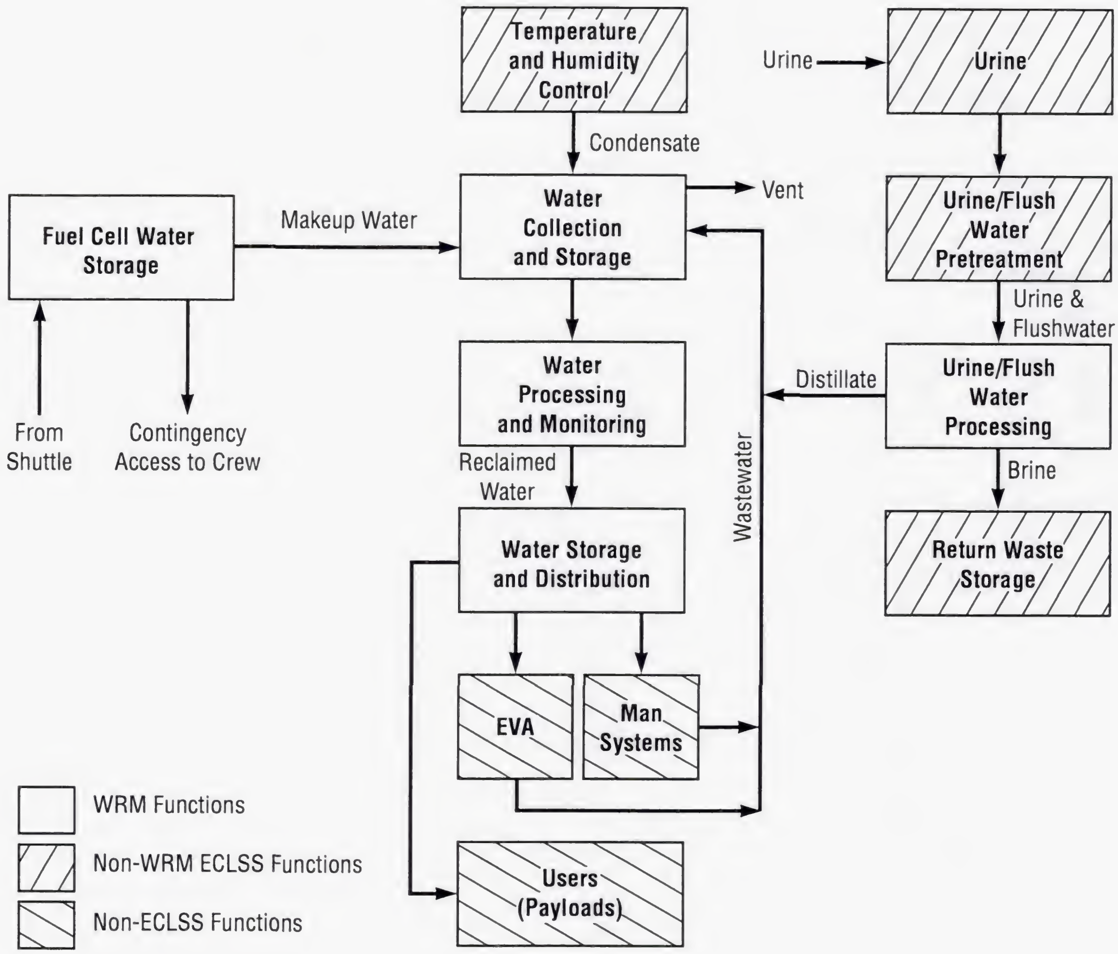
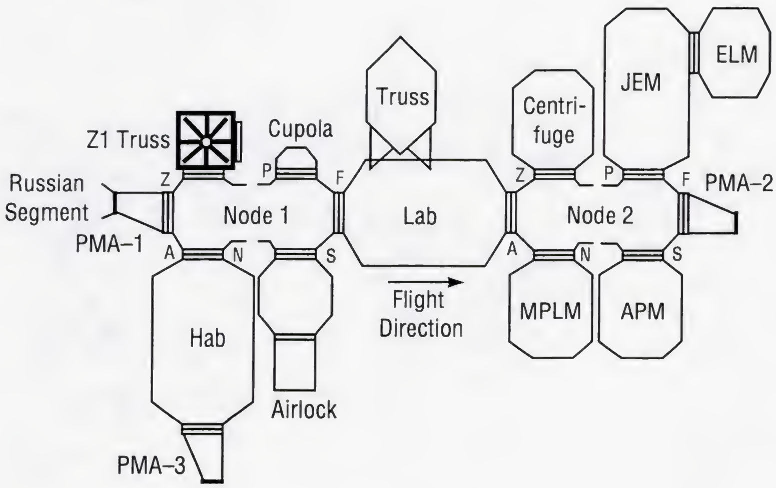


FIGURE 122.—WRM subsystem architecture.

Legend



Self-Sealing Quick Disconnect, Half

Flex Hose

Feedthrough

Mechanical Fitting, Half

Solenoid Valve With Manual Override and Position Indication

Manual Valve

Non-Propulsive Vent

Check Valve

Heater

Temperature Sensor

Potable Water

Wastewater

Fuel-Cell Water

1 Potable water supplied by portable tank.

2 Two flex lines come up with the Water Processor and Urine Processor racks for installation on orbit. One additional flex line is required for the Waste Management Compartment.

3 Contingency Water Container (CWC) available for redundancy.

FIGURE 123.—WRM subsystem.

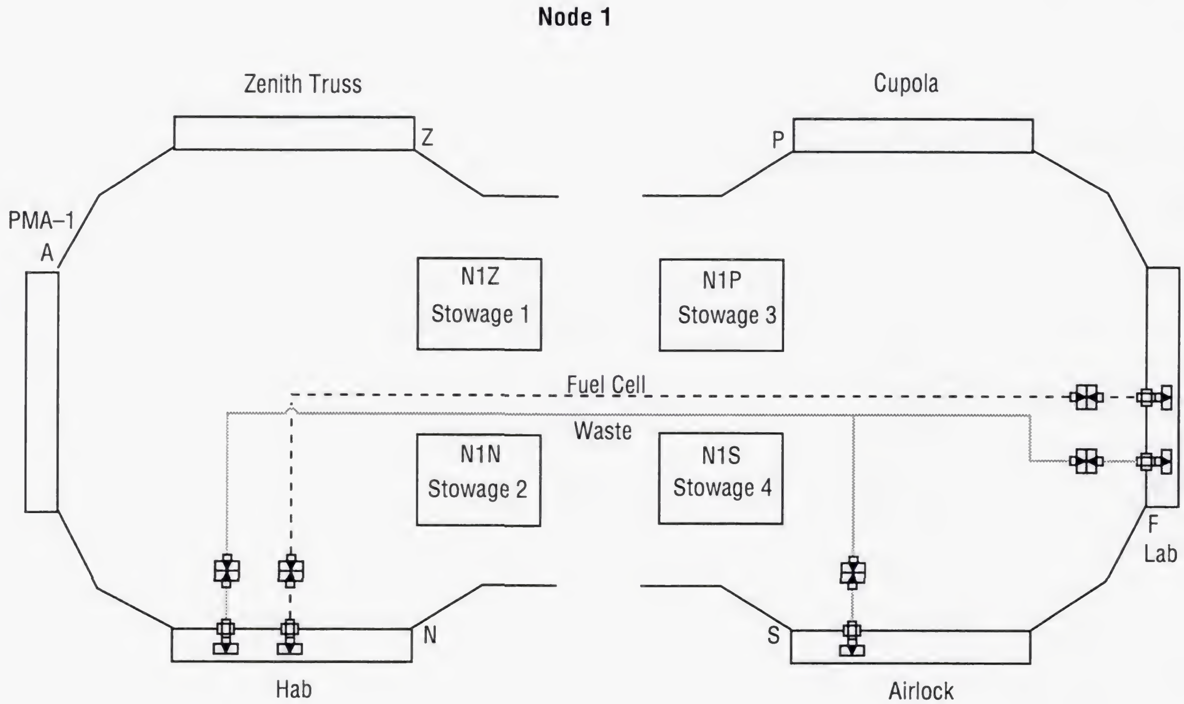


FIGURE 124.—WRM subsystem (continued).

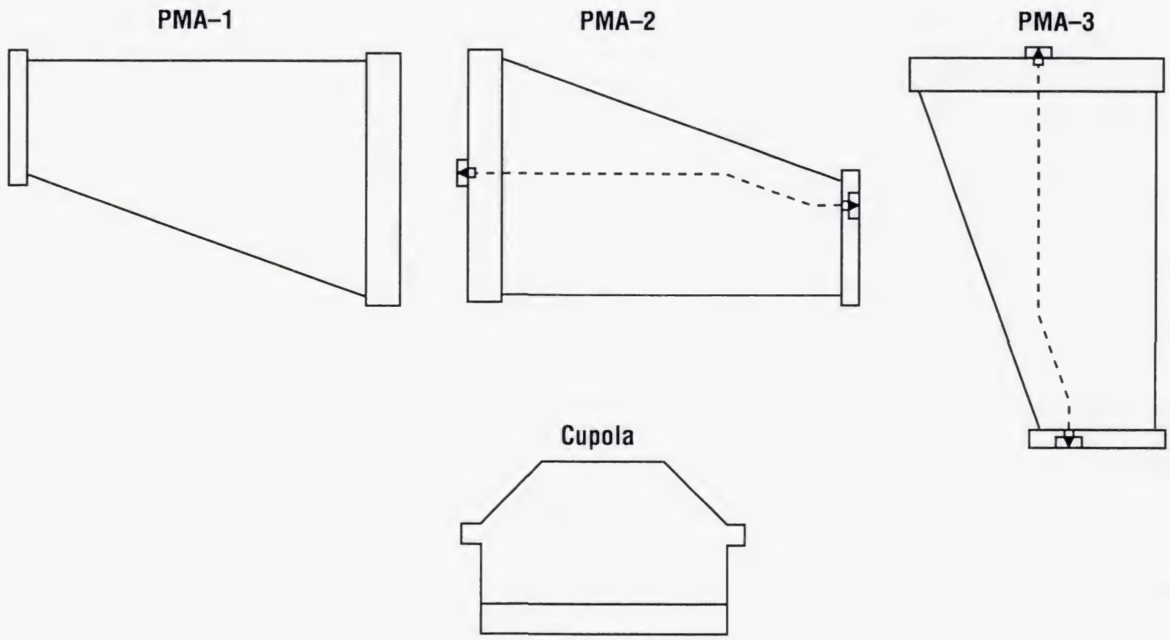


FIGURE 125.—WRM subsystem (continued).

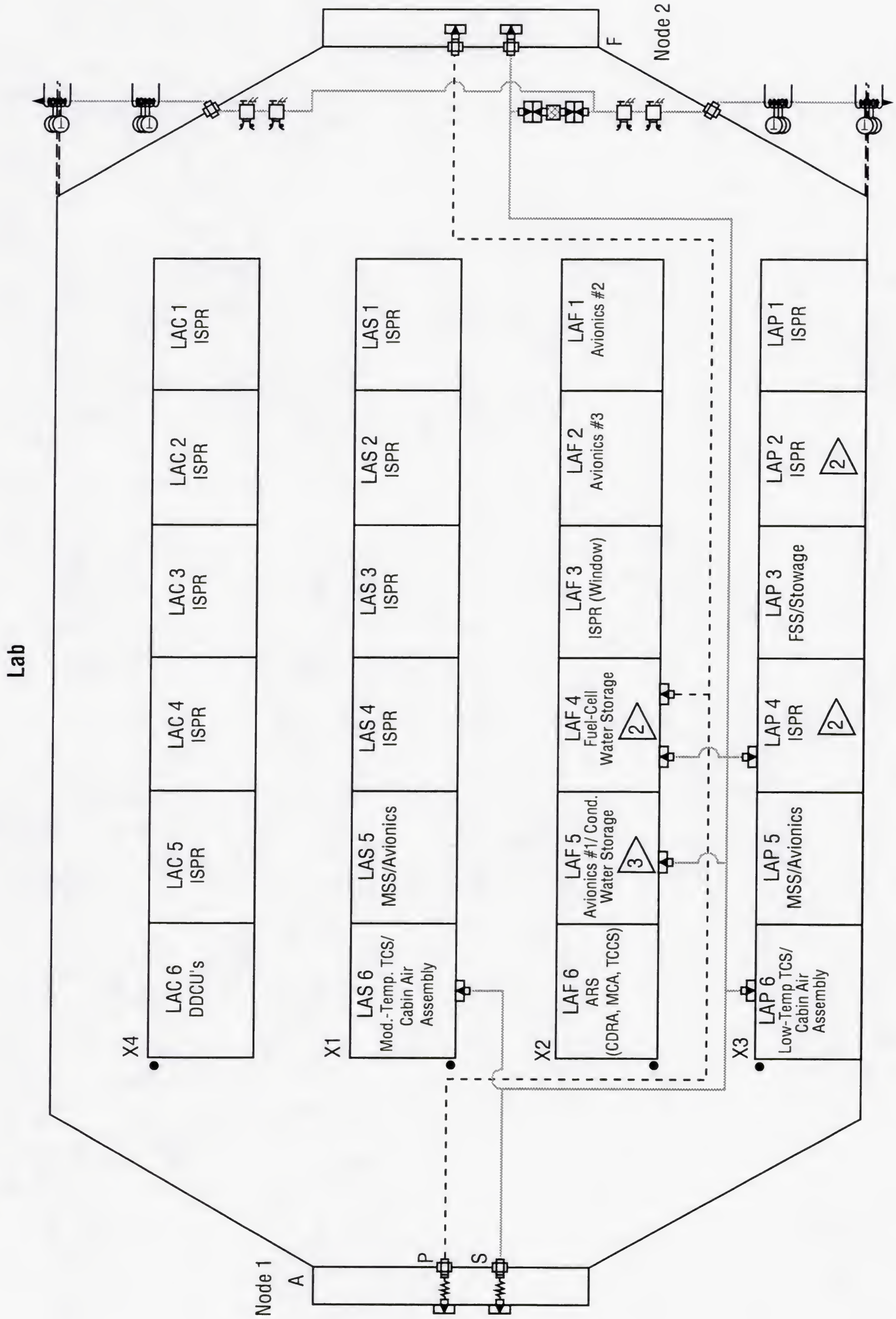


FIGURE 126.—WRM subsystem (continued).

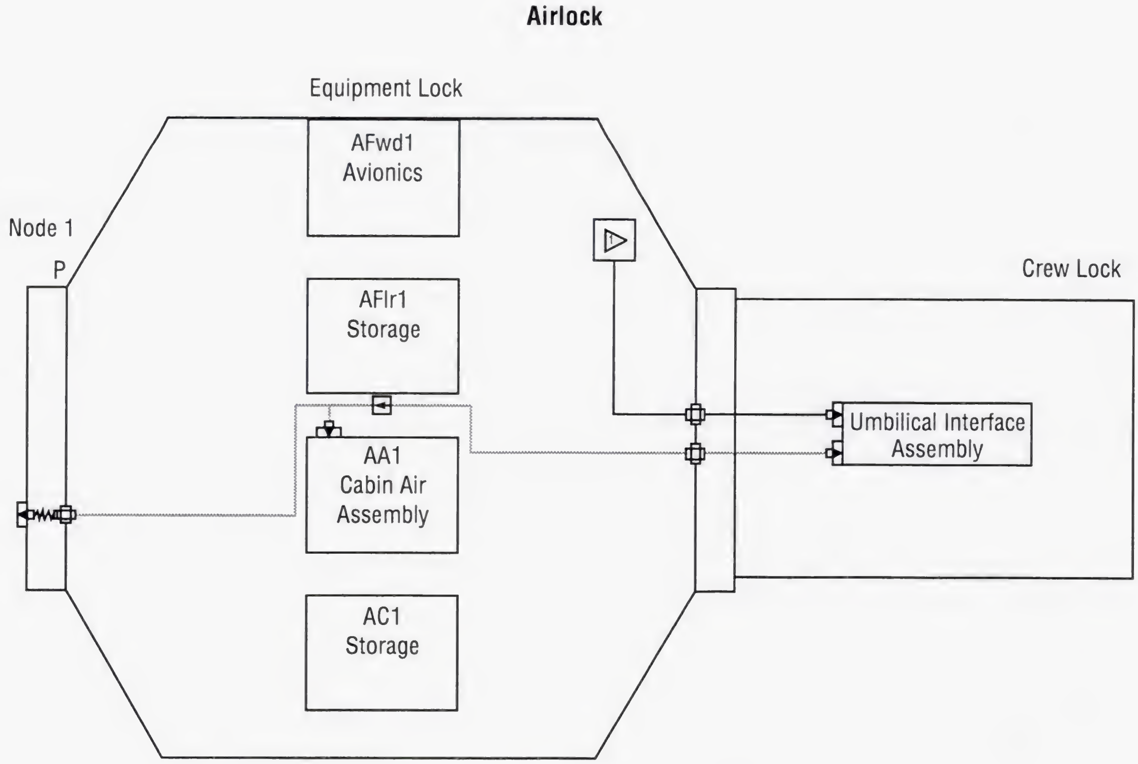


FIGURE 127.—WRM subsystem (continued).

Venting constraints and concerns include:

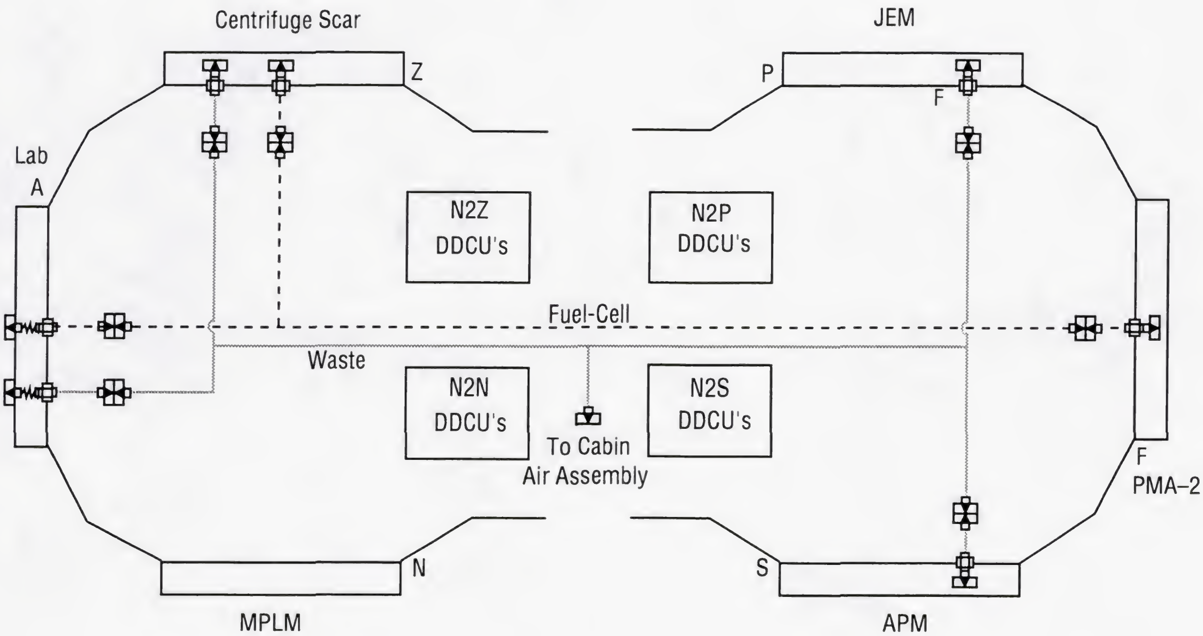
- Scheduling of venting times—No venting is performed during EVA's, space shuttle approach/ departure, space shuttle docked operations, or *ISS* attitude maneuvers.
- Automated venting—Venting time constraints are incorporated into the controlling software.
- Water quantity (Q) in tank—Determining the best times to initiate the manual venting operation since waiting until Q = 60 kg (132 lb) may not always be prudent.
- Perform venting operation in sunlight when feasible.

3.6.1.2 Condensate and Fuel-Cell Water Storage Tanks

The condensate tank is located in the Lab and provides for temporary storage of wastewater. The tank has a capacity of 75 kg (165 lb) to provide storage for at least 68 kg (150 lb) of wastewater. The dimensions are 0.39 m (15.5 in) diameter and 0.90 m (35.5 in) length, with a total volume less than 1.7 m^3 (20 ft^3). The tank is a positive expulsion bellows-type, made of an Inconel™ bellows with an aluminum shell, vented to the atmosphere. Wastewater can be received at a rate up to 2.3 kg/hr (5 lb/hr) at a pressure between 101 to 156 kPa (0 to 8 psig) and a temperature between 18.3 and 45.0 °C (65 and 113 °F). There are two quantity sensors that allow automatic control and remote wastewater venting. Water is removed from the tank through the vent assembly or by manual draining via a QD connector. The condensate storage tank is located in rack LAF3 and is connected to the wastewater network.

Fuel-cell-water tanks are located in the Lab (delivered in the MPLM and moved to the Lab) and provide for temporary storage of fuel-cell water received from the space shuttle. Each tank is the same design as the condensate tank. Storage for up to 408 kg (900 lb) of water is provided. The total volume of all fuel-cell-water tanks is to not exceed 4.7 m^3 (55 ft^3). Fuel-cell water can be accepted from the space shuttle at a rate of 109 kg/hr (240 lb/hr) at a pressure between 69 and 207 kPa (10 and 30 psia) and a temperature between 18.3 and 45.0 °C (65 and 113 °F).

Node 2



Centrifuge

FIGURE 128.—WRM subsystem (continued).

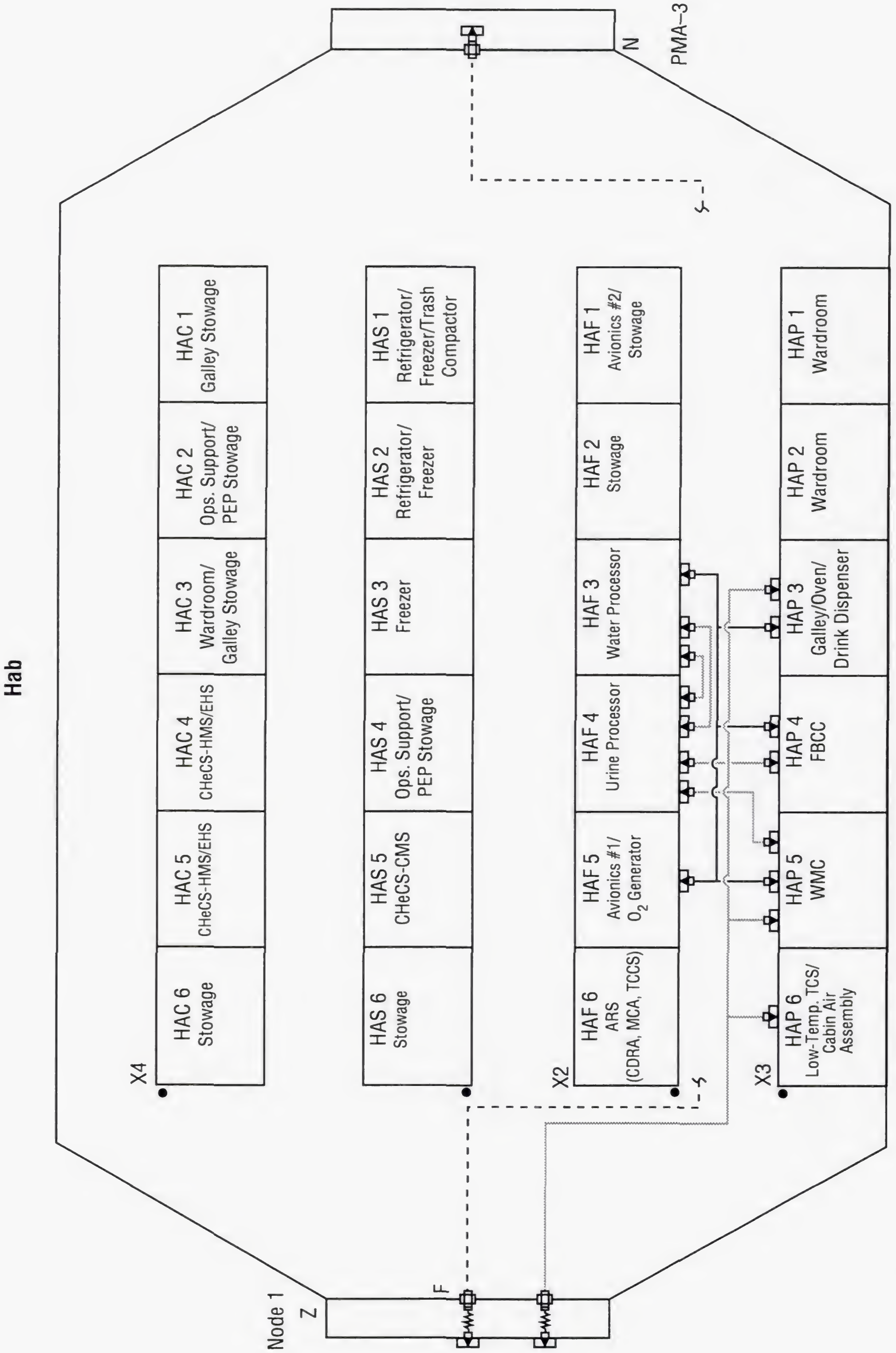


FIGURE 129.—WRM subsystem (continued).

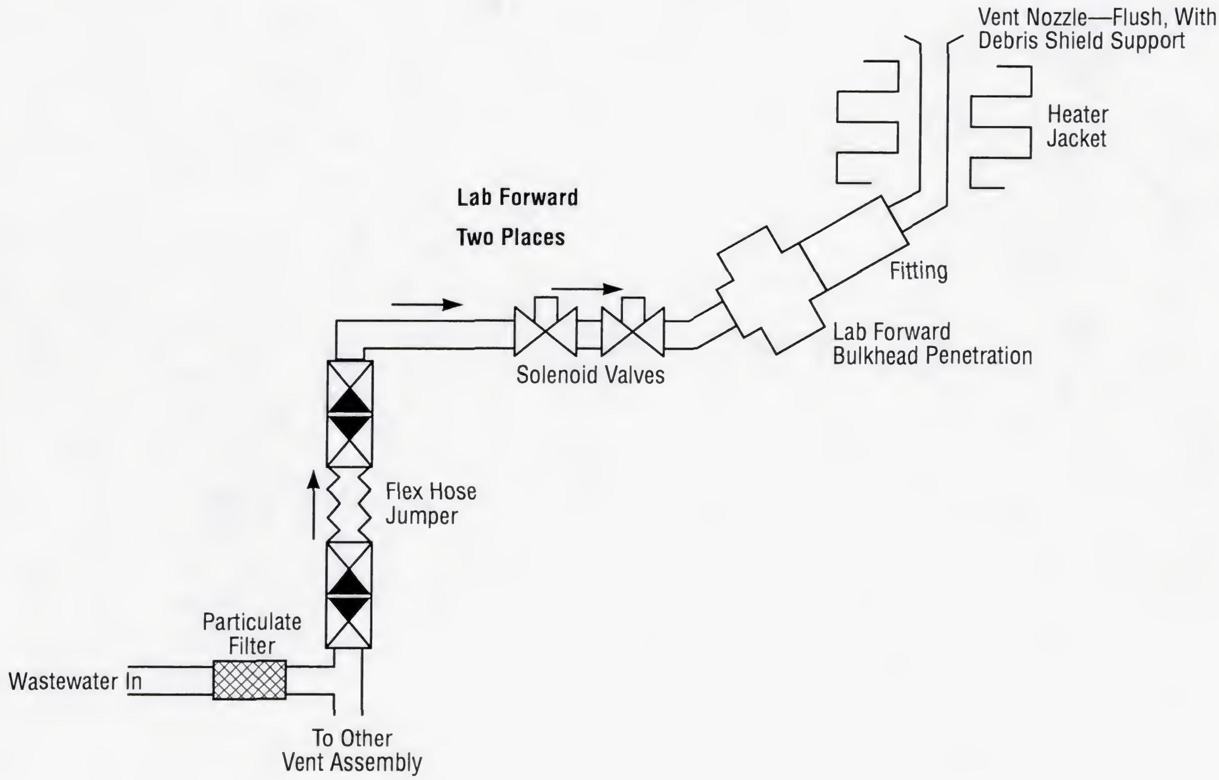


FIGURE 130.—USOS wastewater vent assembly.

Wastewater Vent Location—Lab forward looking aft (A) and Lab port looking starboard (B). Each vent operates at 65 kg/hr (143 lb/hr) at a cabin pressure of 101.3 kPa (14.7 psia). Nominally, both vents are operated simultaneously to provide "non-propulsive" venting. This operation is controlled by the ECLSS software, but may be initiated by crew or ground command.

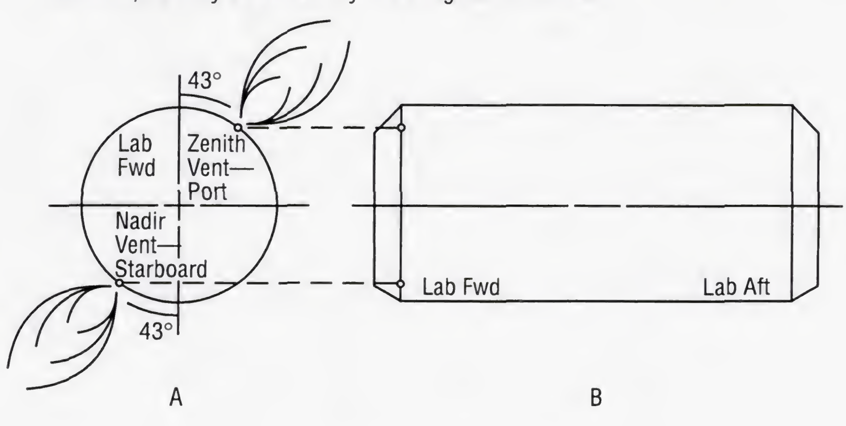


FIGURE 131.—USOS wastewater vent locations.

3.6.1.3 Contingency Water Collection

Contingency storage for up to 43 kg (95 lb) of water is provided by a collapsible soft container that was developed for use on the space shuttle. This container, shown in figure 132, may be connected to the THC during maintenance of the WRM subsystem or to any plumbing that uses the male half of the wastewater QD. The container can be drained by connection to the wastewater vent assembly. The time required to empty the container is approximately 40 min (with a cabin pressure of 101.3 kPa (14.7 psia)). The container has a maximum operating pressure of 55.2 kPa (8.0 psig) with a burst pressure of 193 to 214 kPa (28 to 31 psig). The maximum capacity is 50 to 54 kg (110 to 120 lb). The container has an inner urethane rubber bladder with a Nomex™ fabric outer layer (with handles). A 1.27 cm (0.5 in) outer diameter titanium tube has a QD for attachment of a flexible hose with QD attachments.

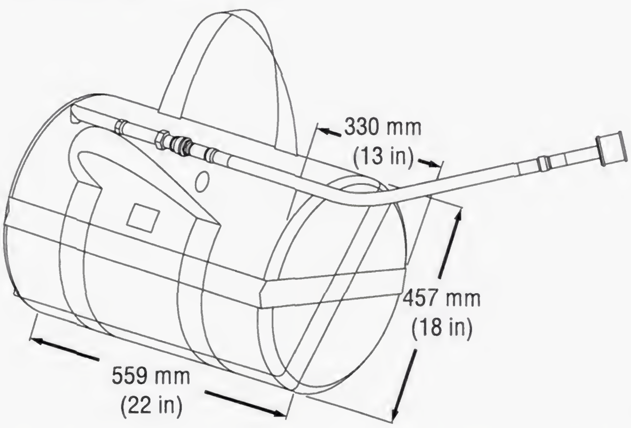


FIGURE 132.—Contingency water collection container.

3.6.1.4 Water Distribution Network

There are three water distribution networks as shown in figures 123 through 129: the wastewater network, the potable water network, and the fuel-cell-water network. The networks consist of rigid metal tubing (1.27 cm (0.5 in) outer diameter titanium) with manual QD's, flexible hoses with QD's, and fixed fittings. There are permanent mountings in the standoffs for the wastewater and potable water interfaces.

The wastewater network extends through all USOS modules and the APM and JEM, and provides for the transfer of condensate/wastewater from the THC CCAA's, urine processor, and other wastewater generating devices to the condensate storage tank, vent assemblies, and water processor. The wastewater network is pressurized to 101 to 156 kPa (0 to 8 psig).

The potable water network is located in the Hab. This network provides for the distribution of potable water from the WP to the drink dispenser, shower, handwasher, waste management compartment, and galley. The potable water network is pressurized to 103 to 206 kPa (15 to 30 psig).

The fuel-cell-water network extends through all USOS modules, although access is only available at PMA–2 and –3 interfaces and at the fuel-cell water storage tank. This network provides for the transfer of fuel-cell water from the space shuttle to the *ISS* fuel-cell water storage tank. The fuel-cell water network is pressurized to TBD kPa (TBD psig).

3.6.2 Monitor Water Quality

The CHeCS provides most of the water quality monitoring. In addition, the PCWQM monitors the purified water downstream of the water processor.

3.6.2.1 Process Control and Water Quality Monitor (PCWQM)

The PCWQM, shown in figure 133, is located in the Hab and monitors the purified water processed by the WP. The water quality is monitored for compliance with the specifications listed in chapter I, table 10 of "Water Quality Requirements" (SSP 41162B), with continuous monitoring by the PCWQM for conductivity, pH, photometric iodine, and Total Organic Carbon (TOC) via infrared (IR) CO_2 detection. (Samples are collected for analysis on Earth for the other compounds.) The process consists of the following steps and components:

- The PCWQM receives purified water from the WP ion exchange bed.
- Conductivity, temperature, and iodine level are monitored continuously, and temperature is used to adjust the pH and conductivity readings. One hundred percent (120 cc/min) of the product water is monitored. The pH sensor is an ion-specific electrode, with a range from 5.0 to 9.0 and sensitivity of ±0.5. The conductivity sensor is electrometric (temperature compensated) and is used for BIT, with a range from 1 to 30 µS/cm (1 to 30 µmhos/cm) and sensitivity of ±0.1 µS/cm (0.1 µmhos/cm). The iodine sensor is photometric, with a range from 0.1 to 6.0 mg/L and sensitivity of ±0.2 mg/L.
- TOC and pH are analyzed continuously in the sample loop. The sample loop monitors a sidestream (1 cc/min) taken from the process loop. The TOC analysis process involves:

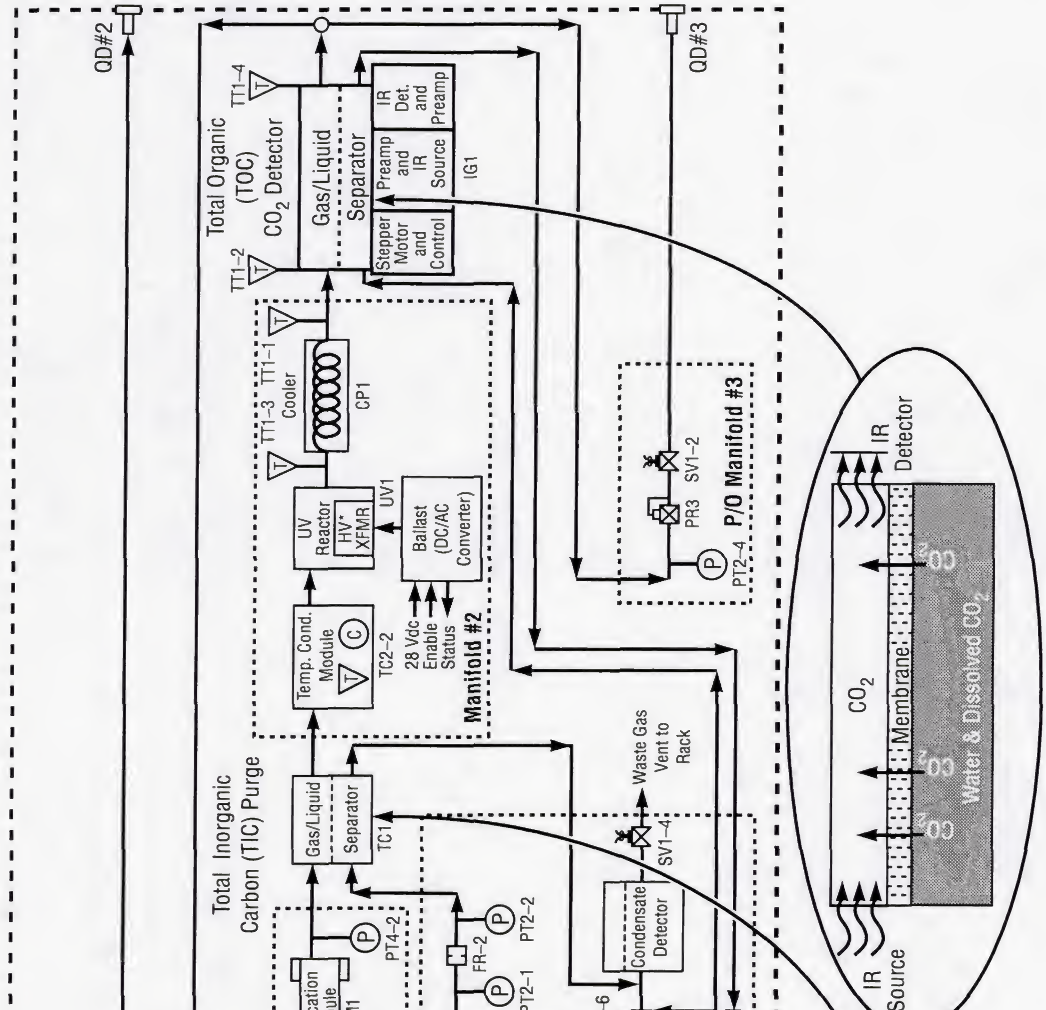


FIGURE 133.—USOS WRM PCWQM.

– Measuring the pH.

– Passing the sample through the solid phase acidifier which converts carbonates and bicarbonates to CO_2.

– Removing CO_2 (derived from carbonates and bicarbonates in the acidified sample stream) with the Total Inorganic Carbon (TIC) Gas/Liquid Separator (GLS). The CO_2 is subsequently vented to the cabin air.

– Oxygen is then mixed with the sample and the mixture is exposed to ultraviolet (UV) light to oxidize the organic carbon to CO_2. The TOC GLS removes CO_2 derived from oxidized organics.

– The CO_2 is then subjected to IR light and an IR detector measures the amount of light absorbed, which is directly proportional to the amount of organic carbon (the TOC) that was present in the sample. The detector has a range from 100 to 1,000 µg C/L and sensitivity of ± 50 µg C/L.

– The TOC sample is then returned to the WP upstream of the ion exchange bed to remove any contaminants that may have been introduced during the TOC analysis process.

The only expendable components are:

- The PCWQM pH calibration module that is replaced every 90 days or longer.
- The Solid Phase Acidification (SPA) module that provides dilute phosphoric acid and is replaced every 90 days or longer.

Nonexpendable components include:

- QD's—To allow disconnection of fluid interfaces
- Manifold assemblies—To direct fluids through the PCWQM
- Three-way solenoid valves—To direct the water sample through the PCWQM
- Two-way solenoid valves—To direct fluids through the PCWQM
- Pump assembly—To pump the sample through the PCWQM
- Gas/liquid separator—To purge gases into the cabin air
- UV reactor—To oxidize organic carbon to CO_2
- Flow restrictors—To limit the flow of O_2 to the gas/liquid separator
- Pressure regulators—To regulate O_2 pressure and water sample return pressure
- Cooler—To cool the sample after the UV reactor
- TOC assembly—To monitor the TOC level
- Temperature/conductivity modules—To monitor the condition of the water sample
- Iodine sensor—To monitor the iodine content of a water sample
- Pressure transducer units—To monitor the water pressure
- pH detectors and probe—To continuously monitor the pH of the sample water
- Temperature sensors—To monitor the temperature of the water sample after the UV reactor and cooler
- CO_2 detector—To measure the amount of IR light absorbed by the CO_2 received from the UV reactor, corresponding to the TOC.

3.6.3 Supply Potable Water

Potable water is distributed from the WP to the use locations via the potable water network.

3.6.4 Supply Hygiene Water

Water for hygiene use is processed in the WP (described in section 3.6.5.1) and meets potable water quality specifications.

3.6.5 Process Wastewater

Wastewater from hygiene uses and condensate from the THC is processed in the WP. Urine is processed in a Vapor Compression Distillation Subassembly (VCDS) to recover water that is then processed in the WP.

3.6.5.1 Water Processor (WP)

The WP is located in the Hab and provides for the processing of wastewater into potable water for crew consumption, hygiene use, experiment payloads, and the water electrolysis O_2 generator. Waste and potable water storage is also provided by the WP. Storage is provided

for at least 59 kg (130 lb) of wastewater and at least 409 kg (900 lb) of fuel-cell water. Wastewater can have up to 10 percent free-gas content by volume (at a temperature of 4.4 °C (40 °F) and a pressure of 143 kPa (20.7 psia). Processed urine can have up to 5 percent free-gas content by volume (at a temperature of 4.4 °C (40 °F) and a pressure of 143 kPa (20.7 psia).

3.6.5.1.1 WP Design

The WP, as shown schematically in figure 134, includes the following components:

- Inlet ORU—Mostly Liquid Separator (MLS), wastewater storage tank, pump, valves, tubing, sensors, etc.
- Filter ORU
- Unibed ORU's—two unibeds
- VRA ORU:
  - Two regenerative heat exchangers and electric heater
  - Gaseous O_2 supply valves and sensors
  - VRA reactor
  - Ion exchange "polishing" bed
- PCWQM ORU's
- Membrane gas/liquid separator
- Product water storage tank ORU—two tanks
- Product water delivery tank ORU
- QD's to aid in maintenance
- Two-way solenoid valves to control the flow of wastewater and processed water
- A three-way solenoid valve to recycle water that needs to be reprocessed
- Relief valves to ensure that the WP does not overpressurize upstream of the particulate filter and the unibeds
- Wastewater storage tank to temporarily store water to be processed by the WP
- Product water storage tank to temporarily store water that has been processed
- Product water accumulator and delivery tank to store and pressurize water prior to distribution
- Pressure regulator to regulate the pressure in the HX and Volatile Removal Assembly (VRA)
- Recirculating pump to regulate delivery of water from the WP wastewater storage tank to the purification process
- Pressurization pump downstream of the MLS to provide pressure to the processor
- Product water pump to pump water from the product water storage tanks to pressurize the product water delivery tank and the potable water distribution system
- MLS to remove free gas from the wastewater prior to filtration and processing
- Gas/Liquid Separator to remove free gas from the processed water downstream of the VRA reactor, which can liberate dissolved gas in the water
- HX to preheat the process water before entering the heater and VRA reactor, and to cool the water exiting the VRA before entering the ion exchange bed
- Heater to heat the process water prior to entering the VRA reactor
- VRA reactor to oxidize low molecular weight alcohols (e.g., methanol and ethanol) contained in the wastewater. The O_2 required for this process is provided by the ACS. Byproducts of the reaction may include aldehydes and carboxylic acids
- The PCWQM to monitor the quality of the processed water, described above
- Quantity sensors to measure the amount of water in each storage tank
- Pressure sensors to monitor the water pressure and pressure drops in the WP. Also, sensors to monitor the O_2 pressure from the ACS
- Conductivity sensors to measure the conductivity of the water prior to the HX's
- Temperature sensors to measure the temperature of the heater and the VRA reactor to gauge performance.

3.6.5.1.2 WP Operation

Wastewater is purified using multifiltration through ion-exchange resins and sorbent materials with catalytic oxidation of trace organics. The purified water meets potable water quality specifications. The process consists of the following steps and components:

- Wastewater is received from the wastewater network.
- Free gas is removed in the MLS.
- Wastewater is temporarily stored until beginning the purification process.
- Wastewater then flows through a particulate filter to remove particulates 0.5 micr ons in diameter.
- "Unibeds" containing sorbent materials and ion exchange resins then remove most of the contaminants from the water.
- The water next is heated to approximately 127 °C (260 °F) before entering the VRA reactor, consisting of a solid catalyst to oxidize low molecular weight organic compounds to CO_2 and organic acids. O_2 for the reaction is provided by the ACS subsystem.
- The water is then cooled in heat exchangers before going to an ion exchange bed where the oxidation byproducts are removed. Excess O_2 is removed by a membrane gas/liquid separator. The ion exchange bed also adds iodine as a biocide.
- The water quality is monitored by the PCWQM. When the water does not meet the required specification it is routed to the WP wastewater tank for reprocessing. Acceptable water is delivered to the product water storage tanks (two 61.3 kg (135 lb) capacity tanks). To protect the internal plumbing from microorganism contamination the recycle line contains a Microbial Check Valve (MCV), consisting of an iodine-impregnated resin in a stainless steel case.
- The product water delivery tank is filled from the storage tanks and provides water to the potable water distribution network.

3.6.5.1.3 WP Performance

The WP processes 9.17 to 13.60 kg/day/person (20.22 to 29.88 lb/day/person) of wastewater (humidity condensate, waste hygiene water, and water recovered from urine) to meet the specification for potable water.

The WP provides an average of 2.8 kg/day/person (6.2 lb/person/day) of water for food rehydration, consumption, and oral hygiene; 6.8 kg/day/person (15.0 lb/person/day) of water for hygiene use; 2.2 kg/day (4.8 lb/day) of potable water for payload use; and up to 3.3 kg/day (7.35 lb/day) of potable water for life science experiments.

3.6.5.2 Urine Processor (UP)

The UP is located in the Hab near the WMC.

3.6.5.2.1 UP Design

The UP process is shown schematically in figure 135. The processing is performed by a VCDS.

Expendable components include:

- Recycle filter tank—Replaced every 30 days. This is a 22 L (0.78 ft^3) tank to collect brine solids when the concentration of solids in the process urine is 25 per cent. A 10 micron filter is in the tank.
- Microbial filter—Replaced every 90 days. It is located in the return line between the output section and input section of the pump. Output water that does not meet the conductivity requirements is routed back to the pump input through this resin bed impregnated with iodine and a check valve.

Nonexpendable UP components include:

- Pretreat urine tank assembly—Located at the input of the UP to receive urine/flush water from the WMC at 145 to 207 kPa (21 to 30 psia). The tank stores a maximum of 20.4 kg (45 lb) of urine/flush water.
- Quick disconnects—To support maintenance of selected UP components (expendable and non-expendable).
- Two-way solenoid valves—To control urine flow and to support non-condensible gas purging and system purging for maintenance.
- Three-way solenoid valve—Located just prior to the UP output interface this valve provides the ability to route reclaimed water to the recycle loop when conductivity exceeds 150 µmhos/cm.
- Manual valves—Located on either side of the recycle filter tank to allow stopping the flow into and out of the recycle tank so it may be removed and replaced.
- Relief valves—To relieve input urine/flush water pressure and to relieve reclaimed water output pressure.
- Check valves—To protect against backflow at various locations, as needed.

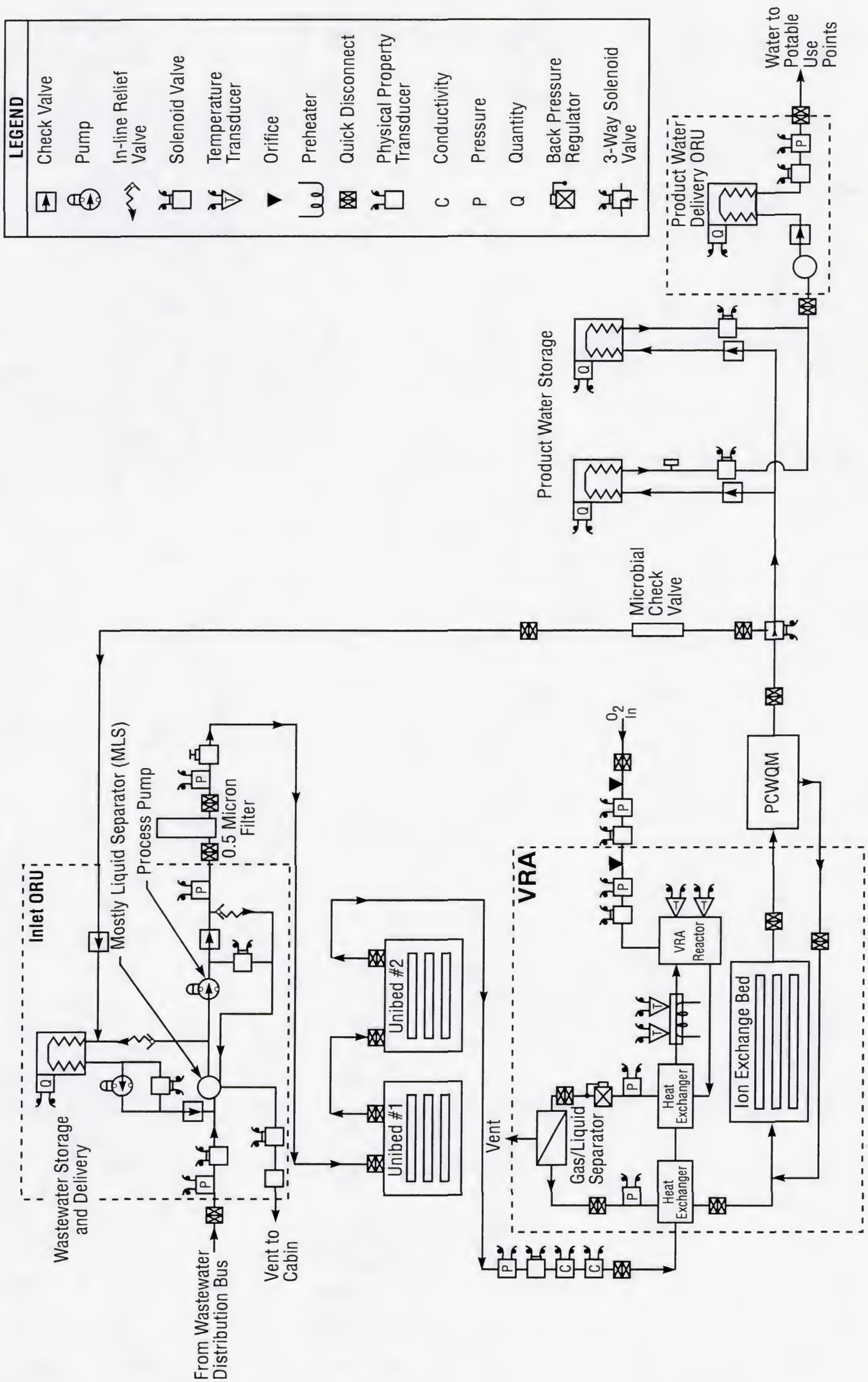


FIGURE 134.—WP schematic.

- Regulator—Located in the purge assembly after the gas/liquid separator to provide the regulation of reclaimed water back into the VCDS output flow.
- Peristaltic pump—A four-section pump operating at 8 rpm. One section pumps unprocessed and recycled urine/flush water to the HX and distillation assembly, two sections operating in parallel retrieve excess wastewater from the VCDS and pump it to the recycle filter tank and recycle loop, and one section pumps the reclaimed condensate from the VCDS and purge assembly to the UP output.
- HX—Wastewater from the VCDS is used to warm the input water. This also cools the wastewater before it reenters the peristaltic pump.
- Distillation unit—Provides zero-gravity distillation of urine/flush water to clean water. The process is:
  - Urine/flush water is fed into the center of a slightly tapered rotating drum (about 180 rpm).
  - A thin film of wastewater is formed on the inside surface of the drum.
  - A compressor (2,400 rpm) lowers and maintains the pressure in the drum at about 4.8 kPa (0.7 psia) to vaporize the water.
  - This water vapor then is removed by the compressor and transferred to the outside of the drum. (Residence time is about 2 min for water entering the drum.)
  - The major impurities are left behind inside the drum.

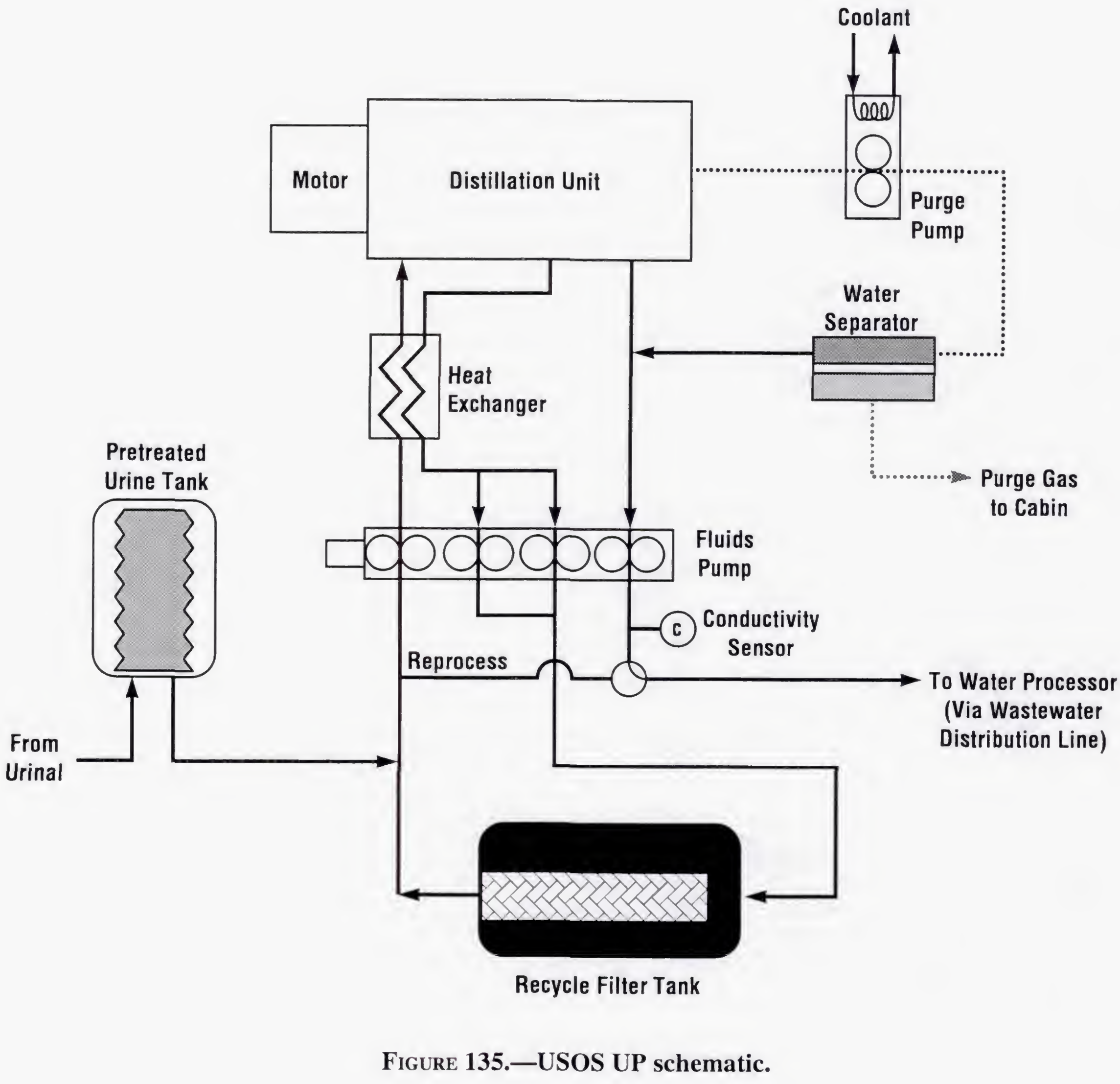


FIGURE 135.—USOS UP schematic.

- The remaining excess wastewater and solid impurities inside the drum are removed by parallel sections of the peristaltic pump.
- The purge pump removes noncondensable gases by operating for 2 min out of every 10 min.

- Purge pump—A four-section peristaltic pump operating at 25 rpm to pass fluids to the gas/liquid separator. This pump periodically removes non-condensable gases from the VCDS (including water vapor that does not condense in the VCDS).
- Gas/liquid separator—A membrane-type separator that is fed by the purge pump. Newly condensed water is separated from the remaining noncondensable gases. Reclaimed water is delivered to the VCDS reclaimed water output line (approximately 2 percent of the total reclaimed water is retrieved by this process). Noncondensable gases are vented to the cabin.
- Quantity sensor—An automatic sensor to measure the quantity of urine in the pretreat tank assembly.
- Speed/rate sensors—To monitor the speeds of the peristaltic pump, the VCDS drum, the VCDS compressor, and the purge pump.
- Temperature sensors—To monitor the VCDS temperature inside the drum and the liquid coolant temperature around the purge pump and still motor.
- Pressure sensors—To monitor the pressures of the peristaltic pump wastewater return, purge pump input, gas/liquid separator line, and the peristaltic pump reclaimed water output. A delta pressure sensor monitors the ΔP across the outputs of the gas/liquid separator.
- Conductivity sensor—To monitor the conductivity of the reclaimed water output from the VCDS.

3.6.5.2.2 UP Operation

Urine is processed at ambient temperature using reduced-pressure VCD, shown in figure 136. The recovered water is then combined with wastewater for processing in the WP (see fig. 134). The process consists of the following steps and components:

- Pretreated urine is received from the waste management urinal and is temporarily stored in the pretreat tank assembly.
- When processing is required, urine is retrieved from this tank and mixed with recycled urine from the recycle loop.
- Urine is fed into the VCDS where water is evaporated, then compressed, and condensed to reclaim pure water. The VCDS is an integrated evaporator/vapor compressor/ condenser that operates at approximately 6.9 kPa (1 psia) and 43.3 °C (110 °F).
- Reclaimed water is pumped out and the conductivity measured. If the conductivity is acceptable, the water is delivered to the wastewater network. If not, it is returned to the urine recycle loop to be reprocessed.
- Nonevaporated urine and solids are delivered to the recycle filter tank where brine solids are removed.
- Recycled urine is mixed with fresh urine from the pretreat tank assembly and the process repeats.
- Noncondensed gases within the VCDS are periodically removed by a purge pump assembly. Reclaimed water from these gases is combined with the VCDS reclaimed water output.
- When the solids content of the recycle filter tank reaches 25 percent by mass, the tank is replaced with a clean tank. The used tank is returned to Earth for cleaning and reuse.

3.6.5.2.3 UP Performance

The UP processes urine for up to six people, at an average rate of 1.56 kg (3.43 lb)/person/day.

3.6.7 Supply Water for Payloads

Potable quality water is provided to user payloads through the potable water network and wastewater may be returned to the WP through the wastewater network.

3.7 Vacuum Services (VS)

The VS equipment is located in the Lab, as shown in figure 137 and 138, and provides the means for experiment pay-loads to have access to space vacuum. The VS includes motorized valves with position indicators, Pirani gauge transducers, cold cathode transducers, and non-propulsive vents.

Note that VS are distinct from vacuum provisions for ECLSS equipment. Some ECLS devices produce gases or have residual gaseous products that must be discarded. In these cases, a separate vent line is provided. For example, the CO_2 removal assembly vents CO_2 through a dedicated vent line that is separate from the payload waste gas vent system. The ECLS venting requirements are discussed in the sections describing the applicable assembly.

3.7.1 Supply Vacuum Services to User Payloads

Some experiment payloads have gaseous byproducts or require a vacuum for operation. For these reasons a means of discarding waste gases to space and providing access to space vacuum is needed. The vacuum exhaust is available to all 13 *ISS* payload rack (ISPR) locations in the Lab. The vacuum resource is available to 9 of the ISPR locations in the Lab.

3.7.1.1 Provide Vacuum Exhaust

The purpose of the vacuum exhaust is to provide waste gas vent capability to user payloads. The allowable pressures that payloads may vent are in the range of 10^{-3} torr to 280 kPa (40 psia). If the pressure exceeds 280 kPa (40 psia) the users must notify the space station controller of the out-of-tolerance condition and take action to reduce the pressure prior to venting. Payload access to the vacuum exhaust is on a scheduled basis and only one payload at a time has access, so that gases venting from one payload cannot adversely affect another payload. The vacuum exhaust vent is controlled automatically by software and motorized valves. Waste gases are vented through a non-propulsive vent. Sensors can measure the pressure in the vacuum exhaust from 10^{-6} torr to 2,070 torr (275 kPa or 40 psia). After a payload has vented to 10^{-3} torr, it can switch to the vacuum resource line to maintain vacuum, if needed.

3.7.1.2 Provide Vacuum Resource

The purpose of the vacuum resource is to provide access to space vacuum to user payloads requiring a vacuum environment to conduct experiments. Some payloads may require vacuum during normal operation, such as for an insulating jacket. The vacuum resource must be able to maintain a vacuum of 10^{-3} torr or less to the payloads. It must also be capable of being used by six or more payloads at a time, providing the combined throughput remains below 1.2×10^{-3} torr-L/sec for nitrogen at 1×10^{-3} torr and 22 °C (70 °F). Vacuum Resource is controlled by manual valves. Sensors can measure the pressure in the lines from 10^{-6} torr to 786 torr (15.2 psia).

3.8 Extravehicular Activity (EVA) Support

The ECLSS supports EVA's by providing services to the joint AL. The AL provides the capability for EVA's, i.e., depressurization, egress, ingress, and repressurization. The AL is a pressurized module mounted on

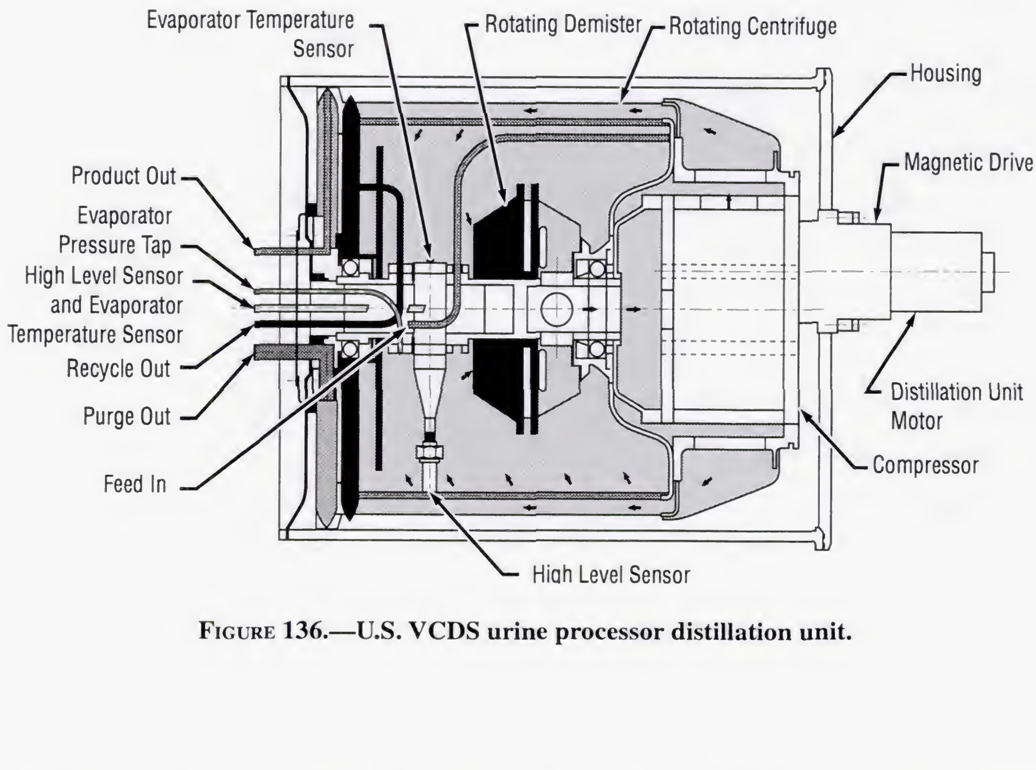


Figure 136.—U.S. VCDS urine processor distillation unit.

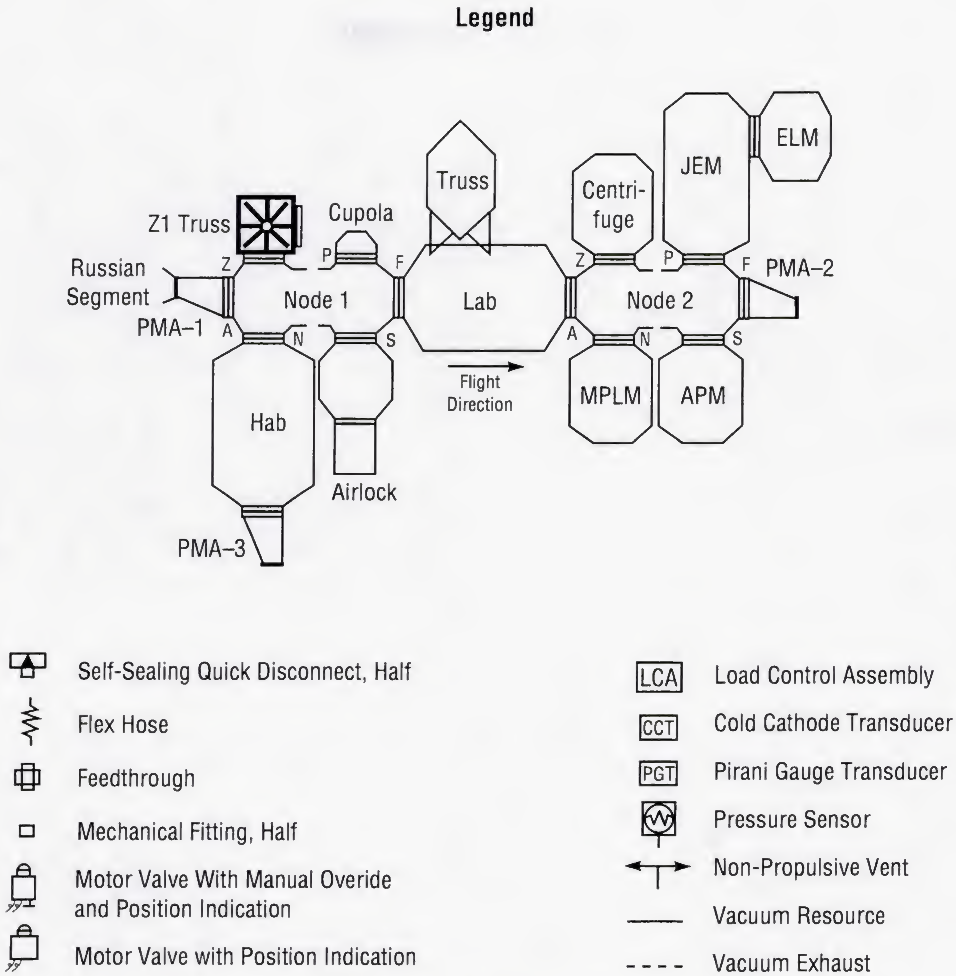


FIGURE 137.—USOS Lab VS.

Node 1 and, as shown in figure 139, consists of two cylindrical chambers attached end-to-end by a connecting bulkhead. (See also chapter I, figs. 9 and 10.) The larger chamber is the equipment lock and the smaller chamber is the crew lock. The equipment lock is used for equipment storage and transfer and preparation for EVA missions. The crew lock is used for egress and ingress of suited crew members and for equipment transfer to and from space.

In operation, the pressure in both AL chambers is reduced to 68.9 to 71.7 kPa (10.0 to 10.4 psia) during the campout period prior to an EVA. This allows the N_2 level in the blood to safely be reduced prior to use of the pressure suits, which operate at 29.63 kPa (4.3 psia). Normal procedures include campout for up to 24 hr.

To exit the *ISS*, the air in the crew lock is pumped to Node 1 (only the crewlock can be completely depressurized). The equipment lock is repressurized to 101.3 kPa (14.7 psia) by opening the MPEV between the equipment lock and Node 1 (there is no hatch on the AL side).

The ECLS functions in the AL are shown in figures 31, 50, 79, 111, and 127. The ECLSS supports preparation for, performance of, and recovery from EVA's. The ECLS functions consist of ACS, THC, some AR, FDS, stored potable water supply, and other EVA support. Potable water is brought to the AL, as needed, to recharge the EMU's.

During campout, PBA's are used to provide O_2 and LiOH is used to remove CO_2. AL components relating to the ECLSS include:

- Smoke detector
- Cabin air assembly
- IMV valve assembly
- Oxygen/nitrogen isolation valve

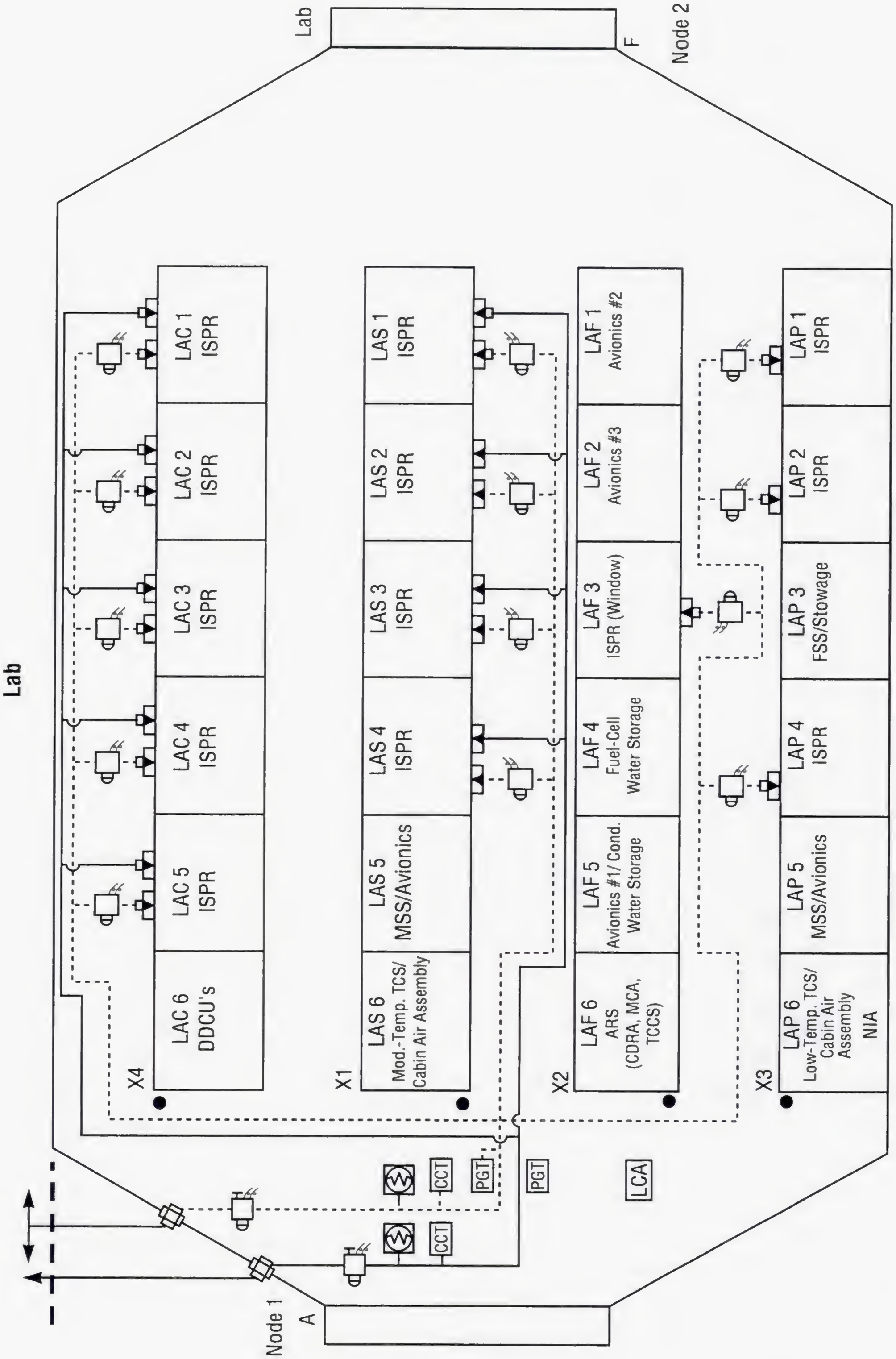


FIGURE 138.—USOS Lab VS (continued).

- PFE
- Stand-alone crew-lock pressure sensor
- Pressure control assembly
- Stand-alone temperature sensor.

The ECLSS-related functions performed in the AL include:

(1) Monitor total pressure in the range of 0.0 to 110.3 kPa (16.0 psia) with an accuracy of ±0.07 kPa (0.01 psia).

(2) Introduce gaseous N_2 from the AL external storage tanks at a rate of 0.045 to 0.091 kg/min (0.1 to 0.2 lb/min) when the total pressure is < 68.9 kPa (10.0 psia). N_2 introduction is prevented when the total pressure is >71.7 kPa (10.4 psia). During campout, the ppN_2 is limited to <54.12 kPa (7.85 psia).

(3) Monitor ppO_2, via the MCA in the Hab or Lab, in the range of 0.0 to 40.0 kPa (5.8 psia) with an accuracy of ±2 percent of the full-scale value.

(4) Introduce low pressure gaseous O_2 from the AL external storage tanks. During campout, the ppO_2 is limited to the range from 17.58 to 20.0 kPa (2.55 to 2.90 psia). The AL ppO_2 concentration is to not exceed 30 percent of the total pressure.

(5) Relieve overpressure to limit the pressure differential to less than 104.8 kPa (15.2 psid).

(6) Equalize pressure with Node 1 prior to opening the hatch.

(7) Monitor air temperature over the range of 15.6 to 32.2 °C (60 to 90 °F) with an accuracy of ±0.5 °C (1 °F).

(8) Remove atmospheric heat to maintain a temperature between 18.3 to 26.7 °C (65 and 80 °F) with an accuracy of ±1 °C (2 °F).

(9) Remove excess moisture from the air during campout to maintain the RH within the range of 25 to 70 percent. The dewpoint temperature is to be between 4.4 to 15.6 °C (40 and 60 °F).

(10) Dispose of removed moisture by delivering humidity condensate to the wastewater bus at a maximum rate of 1.45 kg/hr (3.2 lb/hr) at a maximum pressure of 55.2 kPa (8 psig).

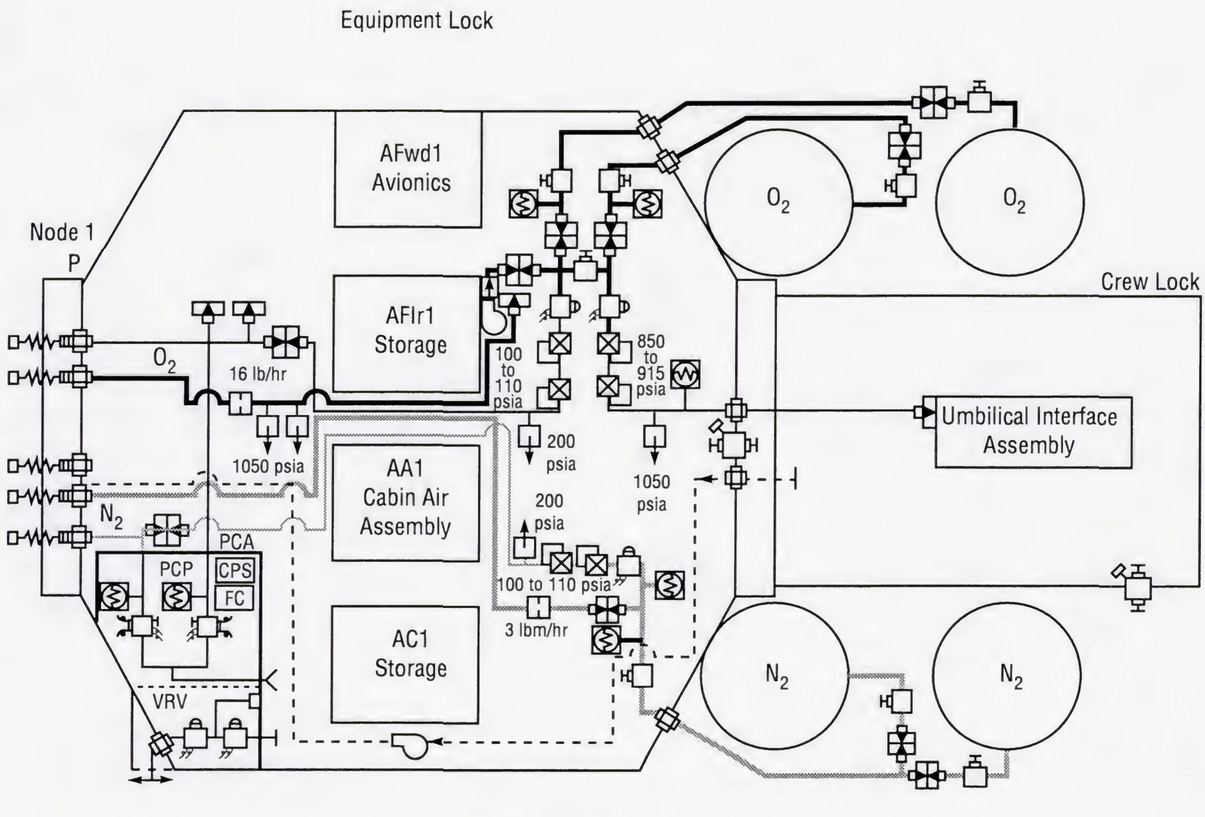


FIGURE 139.—Joint AL AC Subsystem.

(11) IMV with Node 1 during open-hatch operations.

(12) Circulate atmosphere intramodule to maintain an effective air velocity average of 4.6 to 12.2 m/min (15 to 40 fpm) in the cabin aisleway.

(13) Detect a fire event in internal locations that contain a potential fire source.

(14) Isolate fire control zone within 30 sec of detection by removal of power and ventilation at the affected location. The IMV flow is deactivated within 30 sec of annunciation of a Class I fire alarm.

(15) Suppress fires by reducing the oxygen concentration at the fire event location to less than 10.5 percent within 1 min of suppressant discharge.

(16) Recover from a fire by restoring the atmosphere to a total pressure of 95.8 to 102.7 kPa (13.9 to 14.9 psia) and an oxygen partial pressure of 19.51 to 23.10 kPa (2.83 to 3.35 psia) within 75 hr. The AL has PBA's to allow the crew to respond to emergency situations.

(17) Detect rapid decompression in closed-hatch campout operation if an atmosphere pressure change > 0.34 kPa/sec (0.05 psi/sec) occurs and initiate a Class I alarm. In open-hatch operation the AL can detect a rapid decompression in the AL before the *ISS* total pressure decreases by 3.4 kPa (0.5 psi), based on a hole size of 1.27 to 5.08 cm (0.5 to 2.0 in) diameter, and initiate a Class I alarm.

(18) Repair a decompressed module by supporting external operations to repair the AL after a decompression of the AL.

(19) Recover from decompression by providing for repressurization of its atmosphere from space vacuum to a total pressure of 95.8 to 102.7 kPa (13.9 to 14.9 psia) and an ppO_2 of 19.51 to 23.10 kPa (2.83 to 3.35 psia) within 75 hr.

(20) Remove hazardous atmosphere by venting to space to achieve an air pressure < 2.8 kPa (0.4 psia) within 24 hr.

(21) Recover from hazardous atmosphere by repressurization of the AL and reconfiguration as necessary to recover from a hazardous atmosphere event.

(22) Remove CO_2 to limit the $ppCO_2$ to which any one crew member is exposed to a daily average of 0.71 kPa (5.3 mmHg) or less based on the metabolic loads. The maximum limit is 1.01 kPa (7.6 mmHg) peak.

(23) Dispose of CO_2 by removal and disposal of LiOH filters.

(24) Remove airborne particulate contaminants to limit the average particulate level in the AL to 0.05 mg/m^3 (100,000 particles/ft^3) for particles greater than 0.5 microns based on a particle generation rate of 1.4×10^6 particles/min.

(25) Dispose of airborne particulate contaminants by removal and disposal of filters every 90 days.

(26) Remove airborne microbes by filtering particles to less than 0.05 mg/m^3 (100,000 particles/ft^3) for particles > 0.5 microns based on a particle generation rate of 1.4×10^6 particles/min. The microbes in the AL and Node 1 are to be limited to 1,000 CFU/m^3 (28 CFU/ft^3).

(27) Dispose of airborne microbes by removal and disposal of filters every 90 days.

(28) Supply water for potable use from the Hab by portable tank.

(29) Deliver process wastewater to Node 1 via the wastewater bus. This includes EMU return water and humidity condensate.

(30) Support campout prebreathe to accommodate two crew members and the necessary equipment for denitrogenation prior to EVA. An interface with Node 1 supplies oxygen for the prebreathe equipment.

(31) Accept wastewater from two EMU's.

(32) Provide water for two EMU's and umbilical cooling.

(33) Provide O_2 at 6.2 MPa (900 psi) for umbilical operation of two EMU's including in-suit prebreathe and supply/recharge for two EMU's. Provide recharge of an independent O_2 breathing system (walk-around bottle) which supports a single astronaut for 15 min on each charge.

(34) Provide repressurization for ingress at a nominal rate of 0.34 kPa/sec (0.05 psi/sec). Following an EVA, when only the crew lock is at vacuum, the crew lock can be repressurized to 34.5 kPa (5.0 psia) total pressure within 20 sec. When both AL chambers are at vacuum the AL can be repressurized to 34.5 kPa (5.0 psia) total pressure within 60 sec. The maximum emergency repressurization rate for the AL can not exceed 6.9 kPa/sec (1 psi/sec). During an emergency repressurization following an EVA when only the crew lock is at vacuum, both AL chambers can equalize with Node 1 within 80 sec. During an emergency repressurization when both AL chambers are at vacuum, the AL can equalize with Node 1 within 150 sec.

3.8.1 Support Denitrogenation

The space suits that are worn during EVA's operate at 29.6 kPa (4.3 psia) so that less effort is required during use compared with 101.3 kPa (14.7 psia) suits. This allows EVA's to have longer durations, but can also lead to a medical condition commonly called "the bends" in which nitrogen gas dissolved in the bloodstream at 101.3 kPa (14.7 psia) forms bubbles as the pressure is decreased. To avoid this condition, prior to performing an EVA the N_2 gas that is dissolved in the bloodstream must be reduced to a safe level. This is achieved by breathing pure oxygen, or air with a reduced N_2 content, for a period of time before reducing the total pressure. This "prebreathe" period can be performed either in a space suit or in the AL.

3.8.1.1 Support In-Suit Prebreathe

The ECLSS provides O_2. Details are not presently available.

3.8.1.2 Support Campout Prebreathe

The ECLSS provides O_2. Details are not presently available.

3.8.2 Support Service and Checkout

Prior to performing an EVA, the space suit must be provided with supplies sufficient for the duration of the EVA. These supplies include water, O_2, and N_2.

3.8.2.1 Provide Water

Prior to delivery of the Hab, fuel-cell water is used to recharge EMU's. Water is stored in special AL water containers. After activation of the Hab, water is provided from the WP.

3.8.2.2 Provide Oxygen

The ECLSS provides 1.8 kg (4 lb) O_2 for each EVA. Details are not presently available.

3.8.2.3 Provide In-Suit Purge

Detailed information is not presently available.

3.8.3 Support Station Egress

See ACS, section 3.1.

3.8.3.1 Evacuate Airlock

Detailed information is not presently available.

3.8.4 Support Station Ingress

Detailed information is not presently available.

3.8.4.1 Accept Wastewater

Detailed information is not presently available.

3.9 Other ECLS Functions

Other functions of the ECLSS include distributing gases and water to user payloads. Details as to how this is to be done are not presently available.

3.9.1 Distribute Gases to User Payloads

See ACS, section 3.1.

4.0 Safety Features

Safety features include methods of identifying hazardous conditions and methods of responding to hazardous conditions. These features can be classified by the following categories:

- Design to preclude or mitigate the possibility for hazards to occur.
- Design to identify and locate hazards.
- Respond to less severe hazards.
- Respond to severe hazards.

One driving design requirement for the USOS ECLSS is to have at least two barriers to space, based on hazard analyses. For example, in vent lines there are redundant valves in series. Other safety features include monitoring instrumentation, PBA's, PFE's, failure tolerance, and redundant or backup equipment for performing critical functions.

5.0 Maintenance Procedures

Maintenance consists of those functions necessary to maintain or restore system/equipment operability or redundancy, such as equipment and/or ORU removal and replacement, servicing, test, inspection, calibration, and repair. The maintenance objective is to minimize system downtime and maximize availability for operations. The on-orbit maintenance objective is to provide an acceptable level of system functionality and redundancy to support *ISS* survival, crew survival and safety, mission objectives, and payload operations support.

There are two general types of maintenance: preventative and corrective. Preventative maintenance is the planned or scheduled replacement of an ORU. Corrective maintenance is the unplanned or unscheduled replacement of an ORU due to some type of failure. (Corrective maintenance is discussed further in section 6.0.) ORU's are designed to minimize the amount of time required to perform the maintenance operation.

Detailed maintenance procedures are described in other documents. Examples of maintenance procedures are summarized below.

4BMS—There is no scheduled maintenance of the 4BMS. In the event of failure of a component the ORU containing that component can be replaced. (See section 6.1.1.)

THC—Scheduled maintenance of the THC includes replacing HEPA particulate/bacteria filters once per year, inspecting them every 90 days, and cleaning by vacuuming if required. The THC does not have to be switched off during replacement of the HEPA filters. (See section 3.2.3.2).

FDS—There is no scheduled maintenance of the FDS. In the event of failure, smoke detectors can be replaced.

MCA—Scheduled maintenance of the MCA involves four ORU's:

- MS assembly—replaced every 2 yr.
- Pump assembly—replaced every 2 yr.
- Inlet valve assembly—replaced every 10 yr.
- Verification gas assembly—replaced every 3 yr.

The maintenance procedure involves the following steps:

- In the manual state:
  - Send Override Effector commands to enable such other power supplies as may be needed.
  - Command various active and passive BIT's.
  - Exercise individual effectors.
- Override effector command can be used to cancel all overrides, returning to Idle or Failed state.
- Alternatively, initiate the Stop command or Shutdown command.

When manual investigation of the hardware status is needed:

- Power Up, configure as in Normal operational scenario.
- When in Idle or Failed state:
  - Send Override Effector command to enable ±15 power supply.
  - After confirmation of the command, Manual state is entered, and the command is performed.

IMV—Scheduled maintenance of the IMV is not presently planned.

TCCS—Scheduled maintenance of the TCCS involves three ORU's:

- Charcoal bed assembly—Replaced every 90 days or longer, depending on the contaminant load.
- Post-sorbent LiOH bed assembly—Replaced every 90 days or longer, depending on the contaminant load.
- Catalytic oxidizer assembly—Replaced in the event of a failure and once for each entire year of service.

Maintenance is performed by sliding the TCCS out of the rack, as shown in figure 140, for access to the ORU's. The ORU's are held in place by captive fasteners, tension latches, tubing, and other connectors. (More detailed information is in LMSC/F369707.)

WM—Scheduled maintenance of the WM involves:

- Waste storage container—Replaced every 7 days.
- Fecal odor/bacteria filter—Replaced every 30 days.

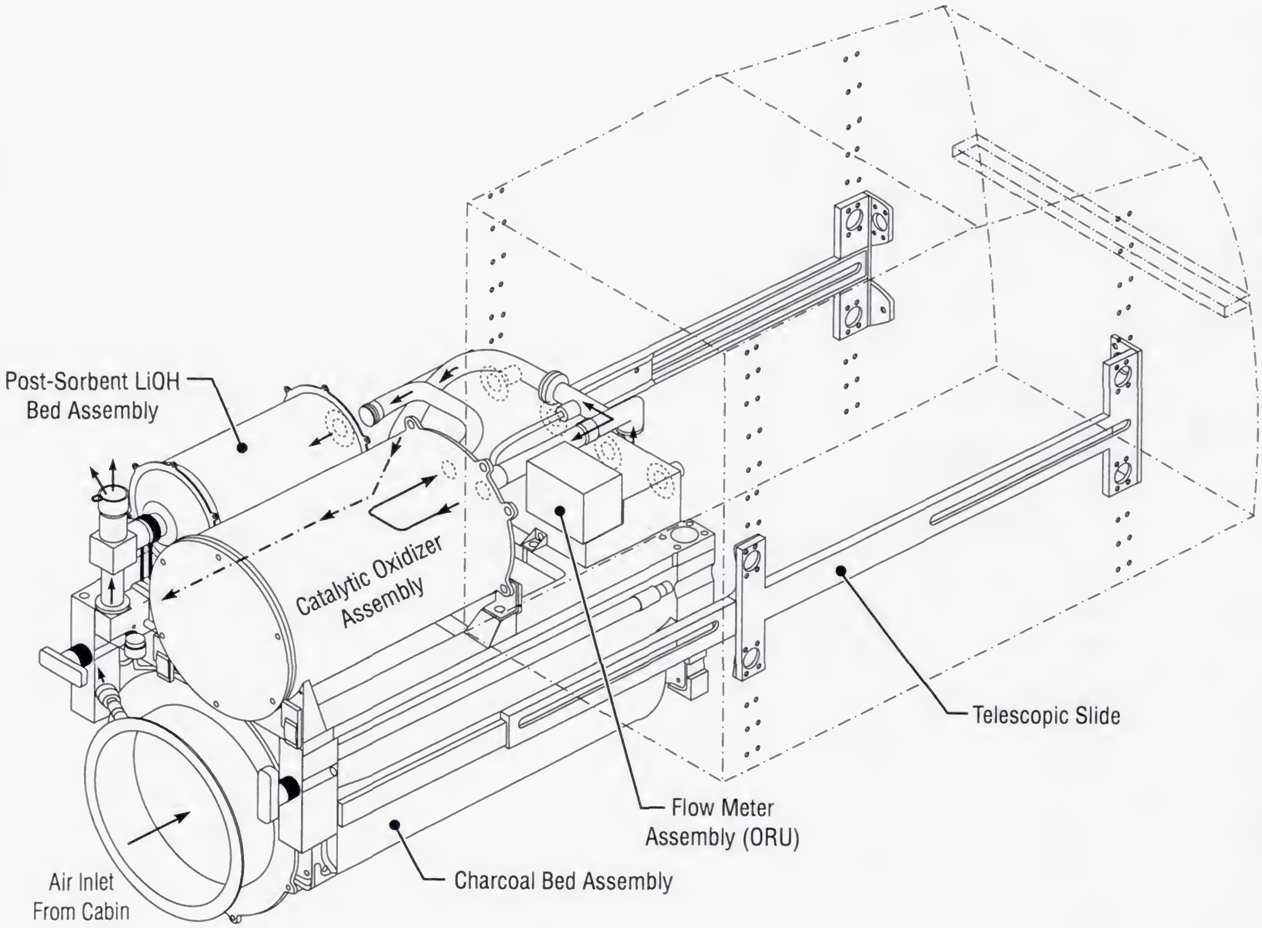


FIGURE 140.—USOS TCCS in extended position for maintenance.

- Plenum odor/bacteria filter—Replaced every 30 days.
- Urine collection odor/bacteria filter—Replaced every 30 days.
- Oxone®/sulfuric acid pretreatment string with filter—Replaced twice daily (for a crew of four).

WRM—Scheduled maintenance of the WRM involves:

- Unibed—Replaced 15 days, or when the conductivity sensor indicates that the bed is saturated.
- Ion exchange bed—Replaced 15 days, or when the conductivity sensor indicates that the filter requires replacement.
- Particulate filter—Replaced 15 days, or when the ΔP sensor indicates that the bed is saturated.
- Urine processor recycle tank/filter assembly—Replaced every 30 days.
- Microbial check valve (in the WP)—Replaced 30 days.
- Microbial filter (in the UP)—Replaced every 90 days.
- SPA module (in the PCWQM)—Replaced when internal verification indicates that the module requires replacement or 90 days.

6.0 Emergency Procedures and Failure Responses

Emergency conditions such as rapid decompression, hazardous atmosphere, and fire are discussed above, in sections 3.1, 3.3, and 3.4, respectively. Emergency situations can be caused by equipment failure, operating error, or external events such as meteoroid impact. Responses to these failures are addressed in this section.

During the process of designing equipment, an exhaustive Failure Modes and Effects Analysis (FMEA) is performed which is used to evaluate the effects of the failure of each hardware item and software command. As shown in figure 141, the effects of failures are classified according to how critical the effects are and a Critical Items List (CIL) is prepared which lists the Criticality 1 and 2 single-failure points. These terms are defined as:

- Criticality 1—Loss of function will result in loss of life or vehicle.
- Criticality 2—Loss of function will result in loss of mission.
- Criticality 3—All other failures.

Where redundancy of the function is present, the following additional ratings are used:

- Criticality 1R—Loss of function redundancy will result in loss of life or vehicle.
- Criticality 2R—Loss of function redundancy will result in loss of mission.

The CIL is used during preparation of on-orbit maintenance procedures and mission rules. Based on the results of the FMEA, the equipment may be redesigned to avoid the worst effects.

6.1 Responses to Equipment Failures

Loss of ECLSS functions may require immediate attention or may have slower effects that are not immediately critical. Loss of AR, especially CO_2 removal, is life threatening and requires quick action to restore the function. For those situations, there are redundant backup systems that can be activated quickly (within a few minutes) to perform the function while the failed unit is being repaired. For loss of equipment that is not immediately life threatening, such as the water processor, there is time to repair the failed unit and a redundant backup unit is not necessary. With the presence of the RS, however, the Russian ECLSS serves as a backup for all of the ECLSS functions, and the U.S. ECLSS serves as a backup for the Russian ECLSS.

6.1.1 4BMS Failure Modes and Responses

As an example, 17 failure modes have been identified for the 4BMS:

- Selector valve 1 failure
- Selector valve 2 failure
- Selector valve 3 failure
- Selector valve 4 failure
- Selector valve 5 failure
- Selector valve 6 failure
- Blower failure
- Pre-cooler failure
- Sorbent bed failure
- Heater failure
- Check valve failure
- Desiccant bed failure
- Air save pump failure
- Rack CO_2 valve failure
- Temperature sensor failure (three)
- ΔP sensor failure
- Absolute pressure sensor failure.

Valve Failure

The failure of a valve to operate properly would be detected by the optical position indicators. A selector valve can lose function due to failure of the motor or of the position indicators. The valve can fail in a specific position (A or B) or in transition.

The 4BMS software will consider the valve failed if the position indicators do not reflect the proper combination of open and closed valves within 10 sec of valve actuation. Upon detection of a failed valve, the 4BMS will transition to the Failed state and the software will report that a valve has failed.

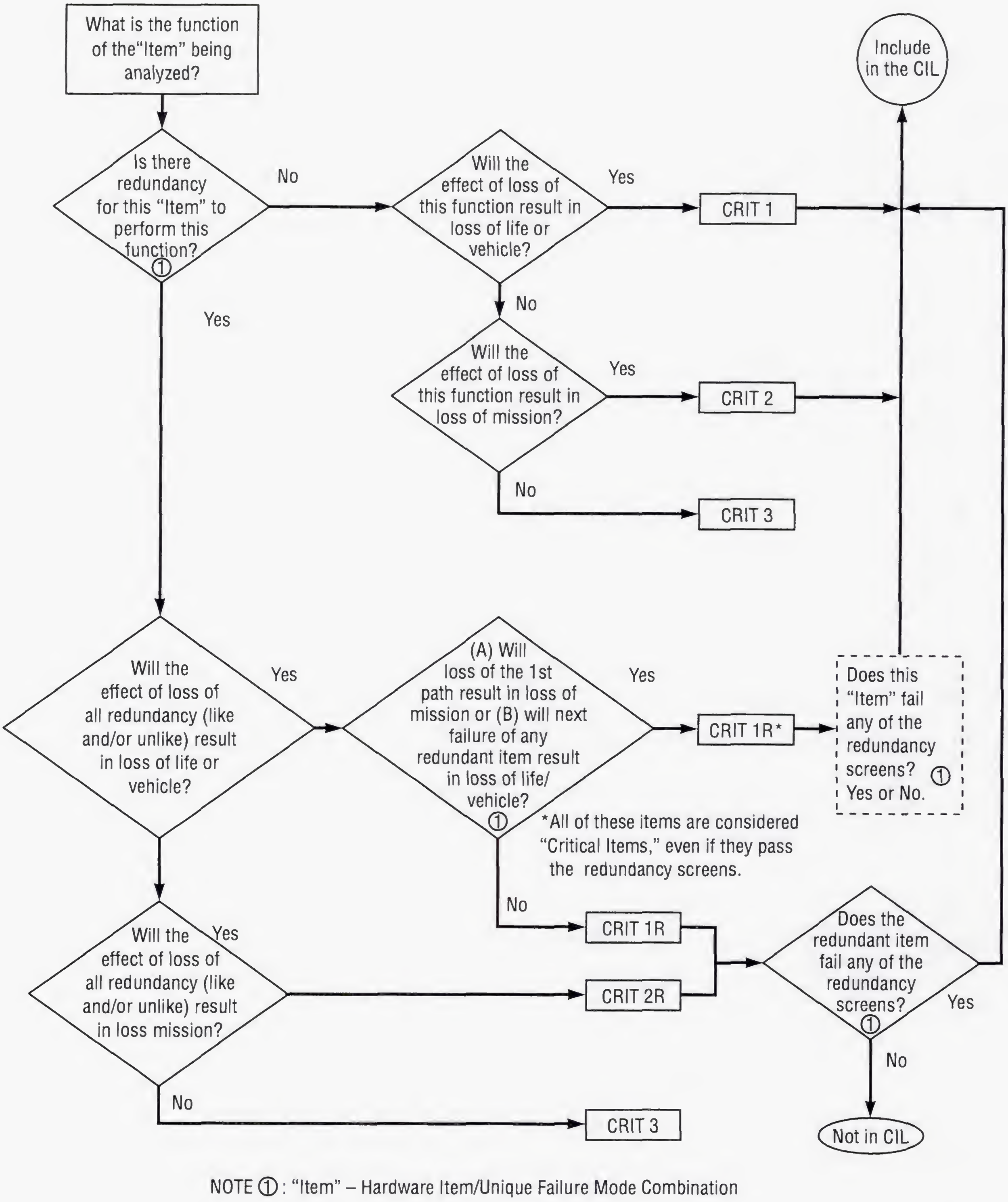


FIGURE 141.—FMEA/CIL screening process to determine criticality rating (NSTS 22206, rev. D).

The 4BMS software BIT will detect valve failure based on no response within 10 sec during valve actuations and based on unexpected position for the operating cycle. The ECLS controller (an MDM) will be able to isolate the failure to the valve level based on the 4BMS active BIT and position indicator changes during static operations, but will rely on the current operating state and valve position indications to confirm whether the motor or position indicator failed. Additionally, the ECLS controller will verify the valve failure by sending override (O/R) commands in an attempt to actuate the valve.

While there are no credible single valve failures that can result in an immediate hazard, the $ppCO_2$ levels can reach SMAC levels within a few hours unless a redundant 4BMS is activated. A potential hazard can result from O/R operation of the 4BMS if valve 5 allows access to space vacuum to the adsorbing bed during CO_2 venting. For automatic safing, upon detection of a failed valve the 4BMS will automatically transition to the Failed state. After 1 hr in the Failed state, the 4BMS will automatically transition to the Off state. For manual safing, if the ECLS controller determines that the position indicator has failed during static operations, the ECLS can command the 4BMS to the Test state and the 4BMS software will perform the active BIT that should verify the valve failure. If the 4BMS software has failed to configure the valves to a safe configuration, the ECLS can perform O/R commands to make sure that the CO_2 vent is isolated from the cabin.

Upon 4BMS failure, the redundant unit will automatically be activated if it is not already operating. Manual recovery procedures depend on the nature and location of the failure:

- Valve failure in transition—The valve must be replaced to restore 4BMS function. There are no workarounds to restore partial functionality as proper positioning of all valves is critical to 4BMS operations. Valves 1, 2, 4, 5, and 6 can be replaced individually; valve 3 is integrated into the Blower/ Precooler ORU and must be replaced as part of this ORU.
- Valve failure in one position—Failure of any valve in a specific position will result in locking the 4BMS configuration into a half cycle. Partial functionality can be regained by O/R commanding of the valves and by exchanging some critical valves within the 4BMS. These workarounds will allow the 4BMS to operate in one half-cycle during which the same beds will sequentially be used to adsorb CO_2 and then be configured for desorption:
  - For failures in valves 1, 2, or 3, valve 4 can be used to isolate the sorbent bed and valves 5 and 6 can be reconfigured to expose the bed to vacuum. The check valve in the other ORU provides isolation.
  - For failure in valve 5, valves 4 and 6 can be used to isolate the sorbent bed during desorption.
  - For failure in valve 4 or 6, the crew must replace the valve with either valve 1 or 2, depending on the configuration in which the valve failed.
- Valve 6 can be exchanged with a failed valve 1, 2, 4, or 5, but the failed valve configuration must be compatible with supporting the CO_2 vent cycle. The crew can exchange a properly functioning valve 6 with a failed valve. The failed valve will then replace valve 6 in the vent line and allow CO_2 venting. The failed valve will not support pumpdown of the sorbent bed to be desorbed. The impact of this workaround is increased loss of cabin atmosphere, but the 4BMS can support both operational cycles. This option may be pursued to restore some redundancy.
- If the valve failure occurs close to 4BMS end-of-life, it may be better to replace the entire 4BMS.
- Additionally, the ECLS controller will verify the valve failure by sending O/R commands in an attempt to actuate the valve.

ORU Replacement

Replacement of the CO_2 sorbent bed/desiccant bed ORU will require no more than 2 hr. The procedure involves the following steps after automated methods have been performed:

- Manual troubleshooting—Visual inspection of components and interface connection verification.
- Removal and replacement (R&R) of failed valves if spares are available. The ARS rack is designed for 4BMS access by removing panels and sliding components out for access.
- If spare ORU's are not available and both 4BMS's are not functioning, ORU's from one 4BMS may be installed in the other 4BMS. (This is assuming that different ORU's failed in each 4BMS.)

The 4BMS ORU's are accessible by removing access panels and sliding the 4BMS out of the front of the ARS rack or by accessing components from the side or rear of the ARS rack. Interface connections that may need to be disconnected include:

- ITCS inlet/outlet
- Dehumidified atmosphere inlet
- CO_2 overboard vent
- Cabin atmosphere return
- Data
- Power.

In the event of valve leakage, the method for detecting leakage is indirect, relying on the MCA's $ppCO_2$ monitoring capability. If the $ppCO_2$ level increases while the hardware is operating properly, then leakage is indicated. The source of the leakage would have to be identified to the ORU level.

6.2 Responses to Operating Error

Ideally hardware and software is designed to prevent the possibility for operating errors to occur. In reality, erroneous commands can be given, components can fail, and undesirable or hazardous consequences may result. In general, the first response may be to switch off power to the affected equipment. Responses to specific operating errors have not been determined at the time of this writing.

6.3 Responses to External Events

External events include penetration of a module shell by a meteoroid resulting in pressure loss (described in section 3.1.5), loss of supply gases stored externally, clogging of a vent line, or other externally caused event.

In the event of externally-caused failures, the response would depend on the severity of the failure. For example, a small leak with mass loss low enough that the PCA can maintain pressure would allow time for the crew to locate and repair the leak. A larger leak that results in loss of pressure in a module would require a different response. Responses to specific external events have not been determined at the time of this writing.

6.4 Venting a Module

In the event that it is necessary to depressurize a vestibule or an adjacent module, a vacuum access jumper can be connected from a 2.54 cm (1 in) diameter vacuum access port on the VRV. Vacuum access is a manual operation. To use the vacuum access port, both vent valves must be closed. The cap on the vacuum access port can then be removed and a flexible jumper attached. The other end of the jumper can be connected wherever access to space vacuum is needed, such as to the MPEV so that a vestibule or adjacent module can be depressurized. With the jumper in place, the VRIV is commanded open. The PCA will require confirmation of the command. When the vacuum access operation is completed, the VRIV is commanded closed and the jumper is removed.

In an emergency such as contamination of the atmosphere or to extinguish a difficult fire, the PCA can perform an emergency vent, by opening the VRIV and VRCV completely. The valves are then kept at full open until the cabin pressure falls below 2.0 kPa (0.29 psia), at which pressure the valves will be closed. The emergency vent procedure is never initiated automatically by the PCA, but must be commanded. Two independent confirmations are required before an emergency vent is performed. The first confirmation command must be received within 30 sec of the Emergency Vent command, and the second confirmation must be received within 30 sec of the first confirmation. At any time during an emergency vent, the PCA can be commanded to stop venting. The atmosphere can be vented to less than 2.0 kPa (0.29 psia) by commanding the PCA to fully open both valves. When the PCA receives these commands, the valves remain open until commanded to close. The PCA must have hazardous command confirmation for each command to open a vent valve.

CHAPTER III: THE EUROPEAN, JAPANESE, AND ITALIAN SEGMENTS ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEMS

1.0 Introduction

The European, Japanese, and Italian segments of the *ISS* consist of the Columbus Attached Pressurized Module (APM) (provided by ESA), the Japanese Experiment Module (JEM) with an ELM (provided by NASDA), and the Mini-Pressurized Logistics Module (MPLM) (provided by ASI). All the modules are sized to be transported in the space shuttle cargo bay. Descriptions of the elements and their integration into the *ISS* are given in "Chapter I: Overview." These modules are attached to Node 2 of the USOS, as shown in chapter I, figure 1.

1.1 The APM, JEM, and MPLM ECLS Functions

The APM, JEM, and MPLM ECLS functions are summarized in table 33. These segments are laboratory and storage facilities, so the full range of ECLSS functions are not provided. The basic requirements for the *ISS* ECLSS are discussed in chapter I. The requirements that apply to the APM, JEM, and MPLM relate to THC, ACS, and FDS. In general, the requirements for these functions are the same as for the USOS, but some specific requirements may be different. In addition, the APM and JEM have payload support requirements.

1.2 Commonality of Hardware

Some ECLS hardware is used in more than one segment of *ISS*. This is especially true for the APM and the MPLM. The ECLS common hardware is listed in table 34.

TABLE 33.—*The ECLS functions performed in the APM, JEM, and MPLM.*

Atmosphere Control and Supply (ACS) functions are mostly provided by the USOS and RS. The APM, JEM, and MPLM provide cabin pressure sensors, depressurization assemblies, positive pressure relief assemblies (for when the module is isolated), and pressure equalization valves in the hatches. The APM, JEM, and MPLM also provide negative pressure relief during transportation. The APM and JEM supply N_2 to payloads. The APM, JEM, and MPLM are exempt from the requirement to respond to rapid decompression, and rely on the USOS.
Temperature and Humidity Control (THC) consists of conditioning the atmosphere by Common Cabin Atmosphere Assemblies (CCAA) located in the APM and JEM. The MPLM relies on the USOS.
Atmosphere Revitalization (AR) is provided mostly by the USOS or RS. In the APM and JEM, particulates and airborne microorganisms are removed from the atmosphere by HEPA filters in each segment. (The MPLM relies on the USOS.) Atmospheric samples are collected by the Sample Delivery System (SDS) and delivered via tubing to the Lab for analysis in the MCA.
Fire Detection and Suppression (FDS) consists of smoke detectors at strategic locations, PBA's, and manually-operated PFE's for fire suppression.
Waste Management (WM) is provided by the USOS or RS, and waste is returned to Earth in the MPLM or burned in the Earth's atmosphere in a Progress.
Water Recovery and Management (WRM) is provided by the USOS or RS. Humidity condensate is collected from the CHX's in the APM and JEM and delivered to the USOS.
Vacuum Services (VS) consist of waste gas exhaust and vacuum resource capabilities in the APM and JEM.

Table 34.—*APM, MPLM, and JEM common ECLSS hardware.*

ECLSS Item	APM	MPLM	JEM	Notes/Supplier
Atmospere Control and Supply (ACS)				
Depressurization Assembly	E	E	U.S.	E = Carleton (Spacelab) U.S. = Allied-Signal
Positive Pressure Relief Assembly	E	E	E	E = Carleton (Spacelab)
Negative Pressure Relief Assembly	E	E	E	E = Carleton (Spacelab)
P_{tot} Sensor	E	E	J	E = French supplier J = Japanese supplier
Nitrogen Shutoff Valve	E	N/A		E = Moog
ppO_2 Sensor	E	N/A	N/A	E = Draeger
$ppCO_2$ Sensor	E	N/A	N/A	E = Draeger
Temperature and Humidity Control (THC)				
IMV Fan	E	N/A	U.S.	E = French supplier U.S. = Hamilton Standard
IMV Shutoff Valve	E	E	U.S.	E = Carleton U.S. = USOS hardware
CHX Assembly	E	N/A		E = French supplier
Condensate Water Separator Assembly	E	N/A		E = French supplier
Cabin Temperature Control Unit	E	N/A		E = Kayser Threde
Cabin Air Temperature Sensor	E	E	J	J = Japanese supplier
Avionics Air Assembly (AAA)	U.S.	N/A	U.S.	U.S. = USOS hardware
Air Supply Diffuser	E	E		E = Dornier
Condensate Shutoff Valve	E	N/A		E = Moog
Cabin Fan Assembly (CFA)		U.S.		U.S. = USOS hardware (Node 1)
Atmosphere Revitalization (AR)				
Sample Line Shutoff Valve	E	E		E = Moog
Sample Line Filters				
Fire Detection and Suppression (FDS)				
FDS Panel Indicator	U.S.	N/A	U.S.	U.S. = USOS hardware
PFE	U.S.	U.S.	U.S.	U.S. = USOS hardware
Smoke Sensor	U.S.	U.S.	U.S.	U.S. = USOS hardware
Vacuum Services (VS)				
Venting Device	E	N/A		E = Carleton
Repressurization Valve	E	N/A		E = Carleton
High-Range P Sensor	E	N/A		E = Common to P_{tot} sensor
Low-Range P Sensor	E	N/A		E = Dornier

N/A—Not Applicable

2.0 Descriptions of the APM, JEM, and MPLM Segment ECLSS

The capabilities of the ECLS systems on the APM, JEM, and MPLM segments are listed in chapter I, table 5. The methods, processes, and procedures that perform the ECLS functions are, in general, the same as, or similar to, the methods, processes, and procedures used on the USOS (described in chapter II). ECLS capabilities on the APM, JEM, and MPLM are either:

- Provided by the USOS or RS (described in chapter II and volume II).
- Performed by equipment that is identical to equipment used in the USOS. (This equipment is described in chapter II.)
- Performed by equipment of different design than in the USOS. (This equipment is described in this chapter.)

The ECLS capabilities are described in section 2.1. The monitoring and control system and consoles are discussed in section 2.2. Interconnections between the ECLS systems in different modules are described in section 2.3. Expendable components that must be resupplied are discussed in section 2.4.

2.1 ECLS System Design and Operation

The ECLS system consists of several subsystems that are described for the APM, JEM, and MPLM in sections 2.1.1, 2.1.2, and 2.1.3, respectively.

2.1.1 APM ECLSS Design and Operation

The APM ECLSS, as shown in figure 142, includes ACS (atmosphere sample line), THC, atmosphere supply from the USOS, FDS, a condensate water line from the THC CHX to the USOS, and VS. All other ECLS functions are provided by the USOS or RS.

Atmosphere Control and Supply (ACS) includes monitoring the total atmospheric pressure over the range 1 to 1,048 hPa (0.0145 to 15.2 psia). Control of the ppO_2 is performed by the USOS or RS via IMV. When the APM is connected to the USOS, the USOS provides overpressure relief. For those times when the APM is isolated from the USOS (prior to attachment or when the hatch is closed) excess pressure is released through the APM Positive Pressure Relief Assembly (PPRA). When the module is isolated the atmosphere pressure is maintained to less than the design maximum internal-to-external differential pressure. Venting of atmosphere to space does not occur at <102.7 kPa (14.9 psid) when the APM is isolated. Pressure equalization is performed via the MPEV (see chapter II, section 3.1.4 for more information). The APM is exempt from the requirement to respond to rapid decompression and relies on the USOS instead. ACS also includes responding to hazardous atmospheric conditions. In the event of severe atmospheric contamination, the means to depressurize the APM is provided by the Depressurization Assembly (DA).

Prior to launch there may be circumstances in which the external pressure exceeds the internal pressure. To minimize structural stresses a Negative Pressure Relief Assembly (NPRA) allows external pressure to equalize with the internal pressure.

Temperature and Humidity Control (THC) includes controlling the atmosphere temperature which is selectable over the range 18 to 27 °C (65 to 80 °F). Control of atmospheric moisture is achieved by the CHX portion of the CCAA. Atmospheric circulation within the APM is provided at 0.08 to 0.20 m/sec (15 to 40 fpm) in the cabin aisleway. IMV with the USOS is provided at 229 to 280 m^3/hr (135 to 165 cfm).

The APM THC has some differences from the USOS THC. These include:

- Ventilation in the standoffs and endcones.
- The presence of $ppCO_2$ and ppO_2 sensors (which are not required for the USOS since the MCA measures these gases).
- IMV return through ducts rather than through the hatch. (The capability for IMV return atmosphere through the hatch is provided.) (In the USOS this capability is also present, except for the Node 1-to-PMA–1 and Node 1-to-Cupola interfaces. Typically, however, in the USOS the atmosphere return is through the hatches to save power.)
- Sizing the CHX for three people working heavily in the APM versus normal work conditions in the USOS.

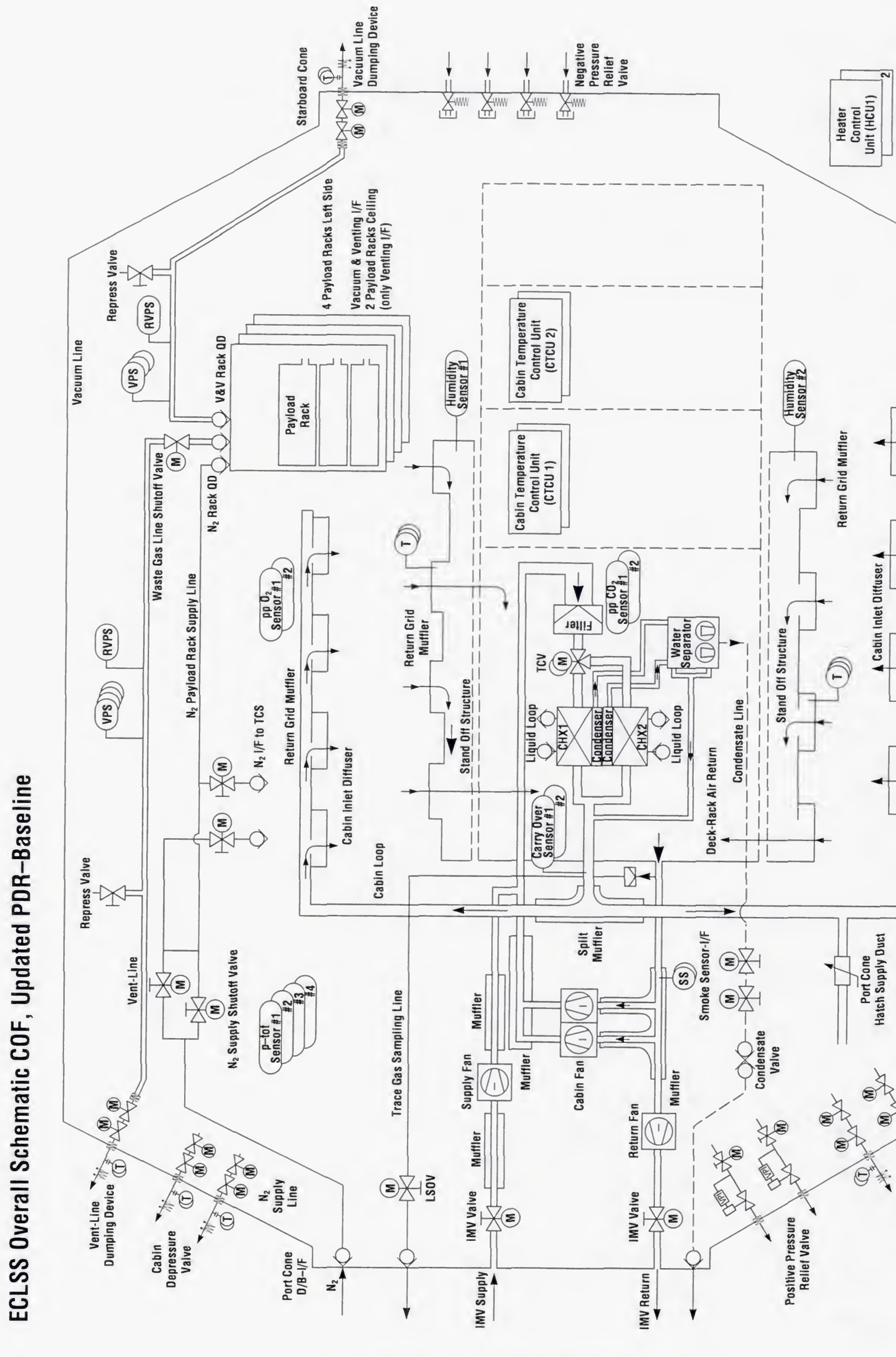


FIGURE 142.—APM ECLSS schematic.

Atmosphere Revitalization (AR) includes controlling the $ppCO_2$ (provided by the USOS or RS via IMV), controlling gaseous contaminants (provided by the USOS or RS via IMV), control of airborne particulate contaminants (via HEPA filters), and control of airborne microorganisms (via HEPA filters). Monitoring of the atmosphere composition is also provided by the USOS, by delivering samples of the atmosphere to the USOS via a sample line.

Fire Detection and Suppression (FDS) includes fire detectors and PFE's. Fire detection is assured via smoke collection and transport in the open volumes of the APM by the air circulation provided by the cabin ventilation loop and the IMV loop. The fire detection concept is one-failure tolerant by the use of two smoke detectors (identical with USOS smoke detectors) at each of two locations:

- Downstream of the cabin fan, for detecting smoke from throughout the APM.

- Downstream of the IMV return air fan, for detecting smoke generated by the fan itself before the Node 2 interface.

Fire suppression is achieved by passive and active methods. Passive methods include the use of self-extinguishing and nonflammable materials. Active methods include removing power, switching off IMV and atmosphere circulation (switching off fans), and the use of PFE's via access ports. As a last resort, the APM can be remotely depressurized to reach a ppO_2 <70 hPa (1 psia) in <10 min. Active ISPR's can support autonomous fire detection capability.

After a severe fire event, the APM atmosphere may need to be vented to eliminate the CO_2 and fire byproducts (smoke) because IMV to the USOS or RS TCCS equipment is not sufficient for atmosphere decontamination.

Waste Management (WM) is provided by the USOS or RS.

Water Recovery and Management (WRM) is provided by the USOS or RS. Wastewater is collected from the THC CHX in the APM and delivered to the USOS for processing into potable water. Water for payload use is provided by the payloads, or it can be provided via portable tanks that are manually filled in the USOS.

Vacuum Services to user payloads include vacuum resource for payloads requiring hard vacuum and vacuum vent to dispose of waste gases.

EVA Support is provided by the USOS or RS.

Other ECLS Functions include distributing gases (N_2) to user payloads.

2.1.2 JEM ECLSS Design and Operation

The JEM ECLSS, as shown in figure 143, includes ACS (atmosphere sample delivery line), THC, atmosphere supply from the USOS, FDS, a condensate water line from the THC CHX to the USOS, module unique gases from the Common Gas Support Equipment (CGSE), and VS. All other ECLS functions are provided by the USOS or RS. Design considerations that are specific to the JEM are listed in table 35.

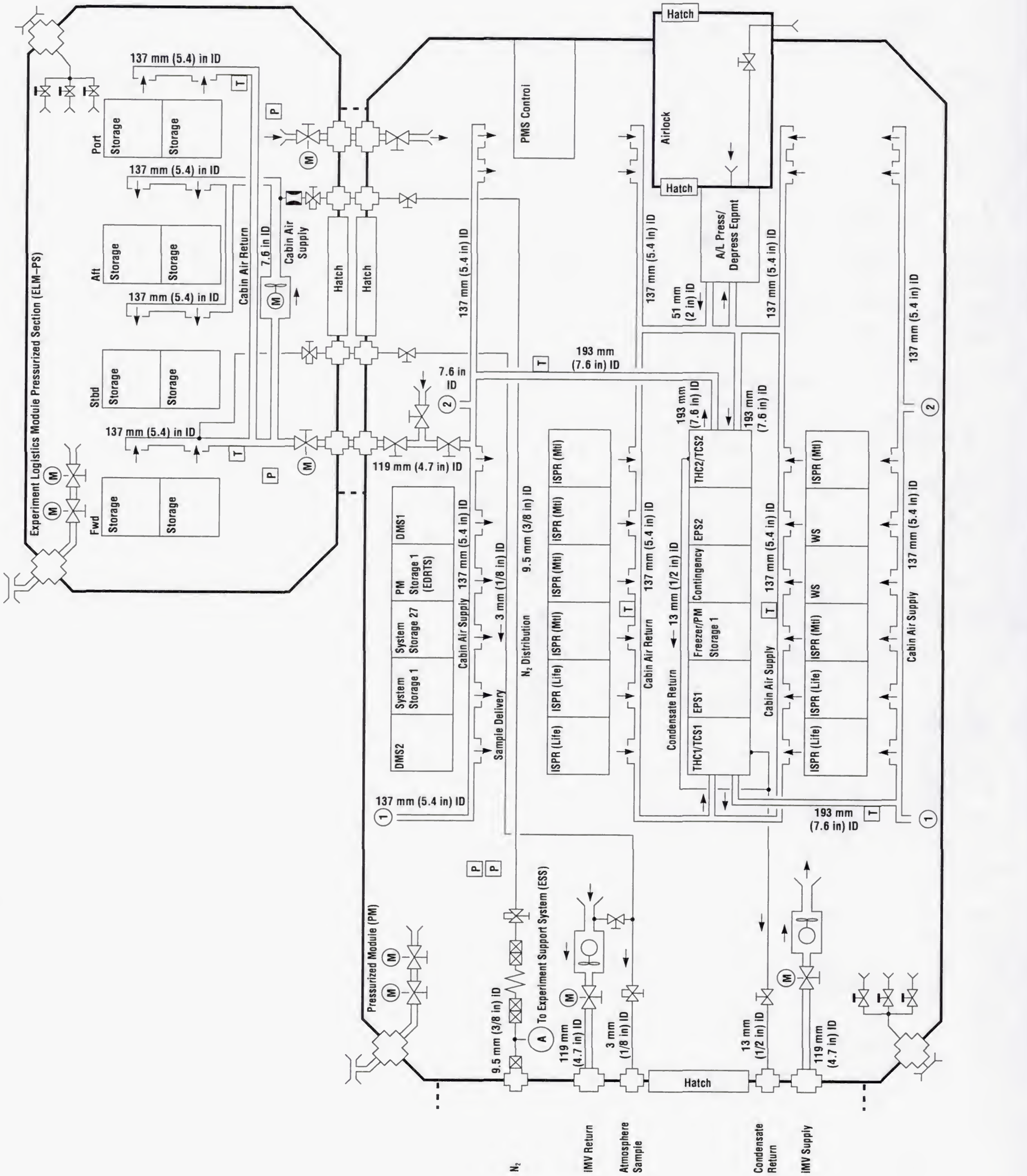


FIGURE 143.—JEM ECLSS schematic.

Table 35.—*JEM ECLSS design considerations.*

Design Loads	Units	Standard Value	Range
General:			
Number of Crew Members	People	2	0 to 4
Time in JEM	hr/day	8	1 to 13
Steady-State:			
PM Volume (empty)	m^3	128	N/A
	ft^3	4,523	N/A
ELM Volume (empty)	m^3	44	N/A
	ft^3	1,555	N/A
PM Avionics Heat Loads	W	1,802	TBD to 3,202
ELM Avionics Heat Loads	W	205	205 to 459
IMV Heat Loads	W	0	–220 to 220
Temporary:			
AL Volume (empty)	m^3	3.0	N/A
	ft^3	106	N/A
AL Avionics Heat Loads	W	900 W for 100 min	TBD
AL-generated Moisture	kg/operation	15 kg/hr for 17min	TBD
	lb/operation	33 lb/hr for 17 min	TBD

The PM ECLS functions include positive pressure release, pressure equalization, N_2 distribution, avionics air circulation, IMV, intramodule circulation, temperature control, atmosphere filtration, smoke detection, PFE, PBA, con-densate delivery to the USOS, vacuum resource, and waste gas exhaust.

The ELM ECLS functions include pressure monitoring, positive pressure release, pressure equalization, IMV, intramodule circulation, temperature control, atmosphere filtration, smoke detection, PFE, and PBA.

The experiment AL ECLS functions include depressurizing and repressurizing the AL volume.

Atmosphere Control and Supply (ACS) includes monitoring the total atmospheric pressure over the range 1 to 1,048 hPa (0.0145 to 15.2 psia). Control of the ppO_2 is performed by the USOS or RS via IMV. When the JEM is connected to the USOS, the USOS provides overpressure relief. For those times when the JEM is isolated from the USOS (prior to attachment or when the hatch is closed) excess pressure is released through the JEM PPRA. When the module is isolated the atmosphere pressure is maintained to less than the design maximum internal-to-external differential pressure. Venting of atmosphere to space does not occur at <99.9 kPa (14.5 psid) when the JEM is isolated. Pressure equalization is performed via the MPEV. (See chapter II, section 3.1.4, for more information.) The JEM is exempt from the requirement to respond to rapid decompression, and relies on the USOS instead. ACS also includes responding to hazardous atmosphere conditions. In the event of severe contamination of the atmosphere, the means to depressurize the JEM is provided by the DA.

Temperature and Humidity Control (THC) includes controlling the atmosphere temperature (selectable over the range 18 to 27 °C (65 to 80 °F)), removing excess atmosphere moisture (by a CHX), circulating atmosphere within the JEM (0.08 to 0.20 m/s (15 to 40 fpm) in the cabin aisleways), and IMV with the USOS (229 to 246 m^3/hr (135 to 145 cfm)).

The design cabin heat loads are based on two people at TBD work load. (See ESA/ASI/NASA ECLS TIM minutes, 24–28 July 1995, JSC, Houston, TX.)

Atmosphere Revitalization (AR) includes controlling the $ppCO_2$ (provided by the USOS or RS via IMV), controlling gaseous contaminants (provided by the USOS or RS via IMV), control of airborne particulate contaminants (via HEPA filters), and control of airborne microorganisms (via HEPA filters).

Atmospheric composition monitoring is also provided by the USOS, by delivering samples of the atmosphere to the USOS via a sample line.

Fire Detection and Suppression (FDS) includes fire detectors and PFE's. Fire detection is assured via smoke collection and transport in the open volumes of the JEM

by the atmosphere circulation provided by the cabin ventilation loop.

Fire suppression is achieved by passive and active methods. Passive methods include the use of self-extinguishing and nonflammable materials. Active methods include removing power and atmosphere circulation (switching off of fans), and the use of PFE's via access ports. As a last resort, the JEM can be remotely depressurized to reach a ppO_2 <70 hPa (1 psia) in less than 10 min. The capability to restore the habitable environment after a fire event is present.

Active ISPR's can support autonomous fire detection capability.

Waste Management (WM) is provided by the USOS or RS.

Water Recovery and Management (WRM) is provided by the USOS or RS. Wastewater is collected from the THC CHX in the JEM and delivered to the USOS for processing into potable water. Water for payload use is provided by the payloads, or it can be provided via portable tanks that are manually filled in the USOS.

Vacuum Services to user payloads include vacuum resource for payloads requiring hard vacuum and vacuum vent to dispose of waste gases.

EVA Support is provided by the USOS or RS.

Other ECLS functions include distributing gases (Ar, N_2, He, CO_2) to user payloads.

2.1.3 MPLM ECLSS Design and Operation

The MPLM ECLSS, shown in figure 144, relies on the USOS or RS more than the APM and JEM.

Atmosphere Control and Supply (ACS) includes monitoring the total atmospheric pressure over the range 1 to 1,048 hPa (0.0145 to 15.2 psia). Control of the ppO_2 is performed by the USOS or RS via IMV. Positive pressure relief is enabled when the module is inside the space shuttle cargo bay and when the MPLM is attached to the USOS but isolated (i.e., when the hatch is closed and the IMV valve is closed). When the MPLM is connected to the USOS overpressure relief is disabled in the MPLM and provided by the USOS. When the module is isolated the atmospheric pressure is maintained to less than the design maximum internal-to-external differential pressure. Venting of atmosphere to space does not occur at <99.9 kPa (14.5 psid) when the MPLM is isolated. Pressure equalization is performed via the MPEV. (See chapter II, section 3.1.4, for more information.) The MPLM is exempt from the requirement to respond to rapid decompression, and relies on the USOS or RS.

When returning the MPLM to Earth, the negative differential pressure across the MPLM shell must be relieved. For this purpose there are five negative pressure relief valves.

Temperature and Humidity Control (THC) functions are primarily performed by the USOS. Latent and sensible heat loads dissipated to the air are removed by the cold air supplied by the USOS through IMV.

Atmosphere Revitalization (AR) includes controlling the $ppCO_2$ (provided by the USOS or RS via IMV), controlling gaseous contaminants (provided by the USOS or RS via IMV), and responding to hazardous atmosphere. Control of airborne particulate contaminants (via HEPA filters) and control of airborne microorganisms (via HEPA filters) is performed by the USOS.

Fire Detection and Suppression (FDS) includes smoke detectors in the intramodule circulation system, since the MPLM does not have separate avionics air cooling. The forward endcone and the freezer/refrigerator racks are the only credible fire risk locations inside the MPLM. The free volume in each enclosure allows the CO_2 mass contained in a PFE to suppress a fire. The freezer/refrigerator rack volumes are located together in a single enclosure. In the event of a severe fire in the MPLM, the module would be sealed, vented, and returned to Earth.

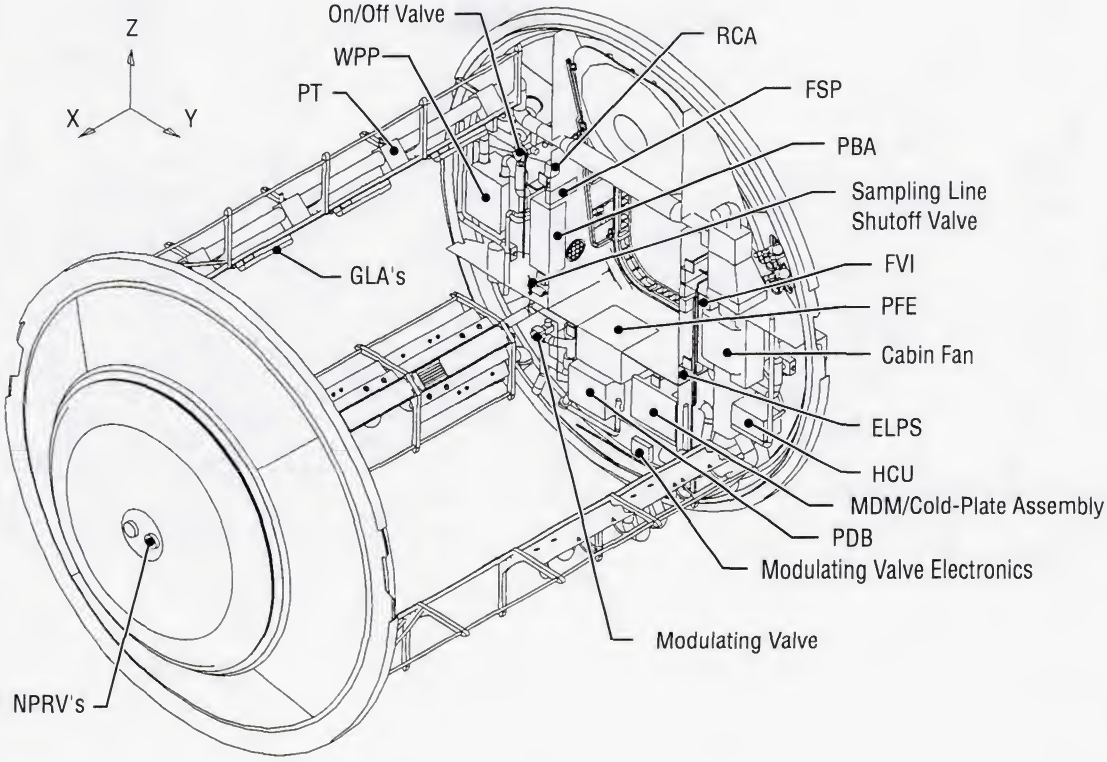
Waste Management (WM) is provided by the USOS or RS. USOS waste products are stored in the MPLM for return to Earth.

Water Recovery and Management (WRM) is not required in the MPLM.

Vacuum Services to user payloads are not required since there are no active payloads in the MPLM.

EVA Support is not required for the MPLM.

Other ECLS functions, such as distribution of gases to user payloads, are not required since there are no active payloads in the MPLM.



MPLM Internal Layout

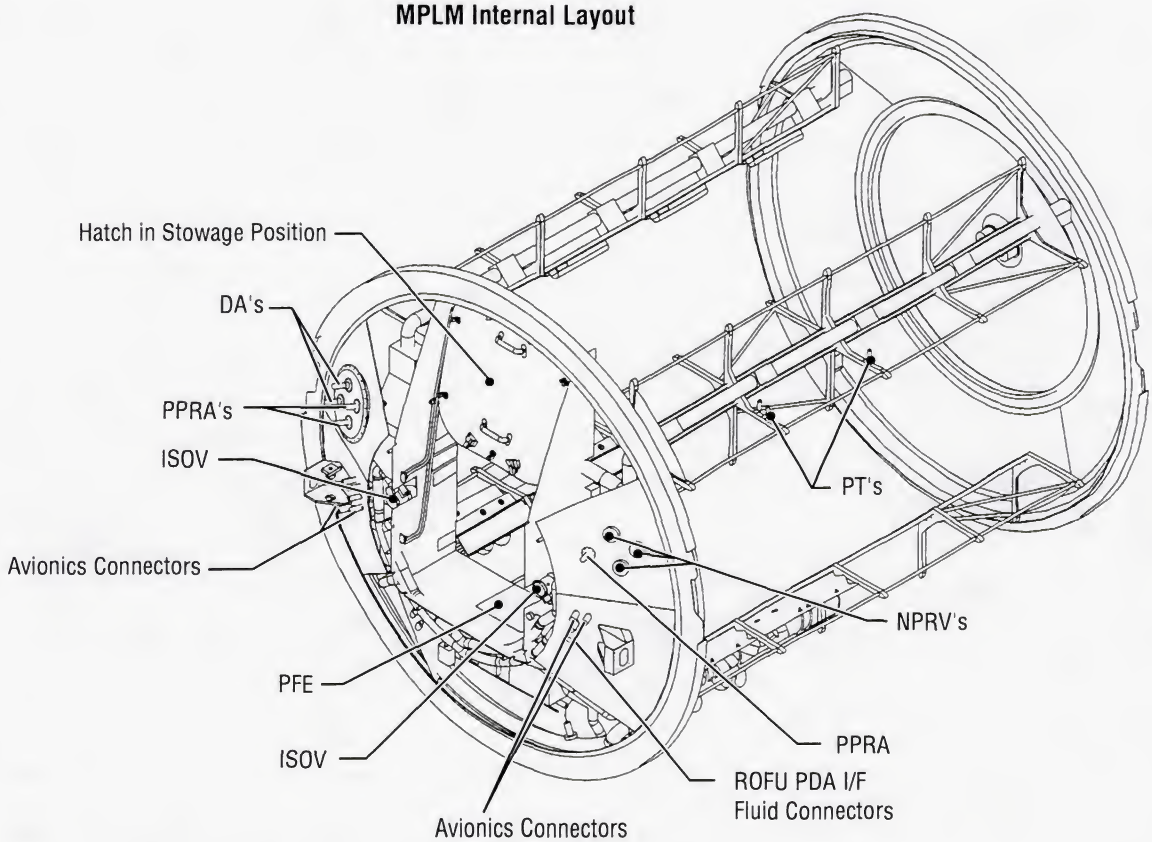


FIGURE 144.—MPLM ECLSS schematic.

2.2 ECLS Monitoring and Control

The ECLS is controlled via laptop computers that can be connected to the C&DH system through data ports located in the modules. This approach is identical to that used on the USOS and is described further in chapter II, section 2.2. The C&W panels in the APM and JEM are identical to those used on the USOS (shown in chapter II, fig. 114). In the JEM there is also a rack-mounted work-station for monitoring and controlling the ECLSS and other systems.

2.3 ECLS Interconnections

ECLS interconnections include fluid interfaces between segments (atmosphere, gases, and water) and mechanical interfaces in each module (e.g., access ports for PFE's). These interfaces are consistent throughout all modules to ensure that PFE's may be used wherever needed. Fluid interface conditions for all interfaces between modules are summarized in chapter II, table 18.

The interfaces with the USOS through Node 2 include:

Coolant Supply and Return—Low-temperature coolant for the ITCS is supplied from the USOS at 0.6 to 5.6 °C (33 to 42 °F) and returned to the USOS at 3.3 to 21 °C (38 to 70 °F) and 124 to 689 kPa (1.24 to 6.9 bar, 18 to 100 psia) and at a flowrate of 0 to 0.063 kg/sec (0 to 8.33 lb/min). The ITCS provides the low-temperature coolant to the THC CHX subsystem.

IMV Supply and Return—Respirable air is supplied from the USOS to the MPLM at 7.2 to 29 °C (45 to 85 °F) and to the APM and JEM at 18 to 29 °C (64 to 85 °C), 95.8 to 104.8 kPa (13.9 to 15.2 psia), and at a flowrate between 3.8 and 4.7 m^3/min (135 and 165 cfm). The supplied air has a dewpoint between 4.5 and 15.5 °C (40 and 60 °F) and a RH between 25 and 70 percent. The maximum O_2 concentration is 24.1 percent by volume. The means to turn off and isolate IMV supply is also present. The IMV interface with Node 2 is shown in figure 145.

By separate ducts, the USOS receives return IMV air at 95.8 to 104.8 kPa (13.9 to 15.2 psia) and at a flowrate between 3.8 and 4.7 m^3/min (135 and 165 ft^3/min). The capability to receive IMV atmosphere during both open and closed hatch operations is present. The means to turn off and isolate IMV return is also present.

Atmospheric sampling is performed via a separate internal line to acquire samples for monitoring (in the USOS) the major constituents in the module atmosphere.

2.3.1 APM Interconnections

The fluid interfaces of the APM are shown schematically in figure 146. The interfaces and their conditions are listed in detail in table 36. The feedthrough connectors are QD's and are identical to the connectors used on the USOS (shown in chapter II, fig. 25). The QD's are designed to last for the entire life of the *ISS*, but may be replaced in the event of failure, providing that both sides of the connector are in pressurized atmosphere (i.e., modules are attached and pressurized). TCS jumpers are threaded (also shown in chapter II, fig. 25) rather than QD's. The condensate from the CHX is delivered to the USOS via a dedicated condensate return (wastewater) line. The conditions in this line at the interface with the USOS are also listed in table 36.

The IMV supply and return atmosphere conditions are described in table 37. The condition of the atmosphere samples at the interface with the USOS are described in table 38.

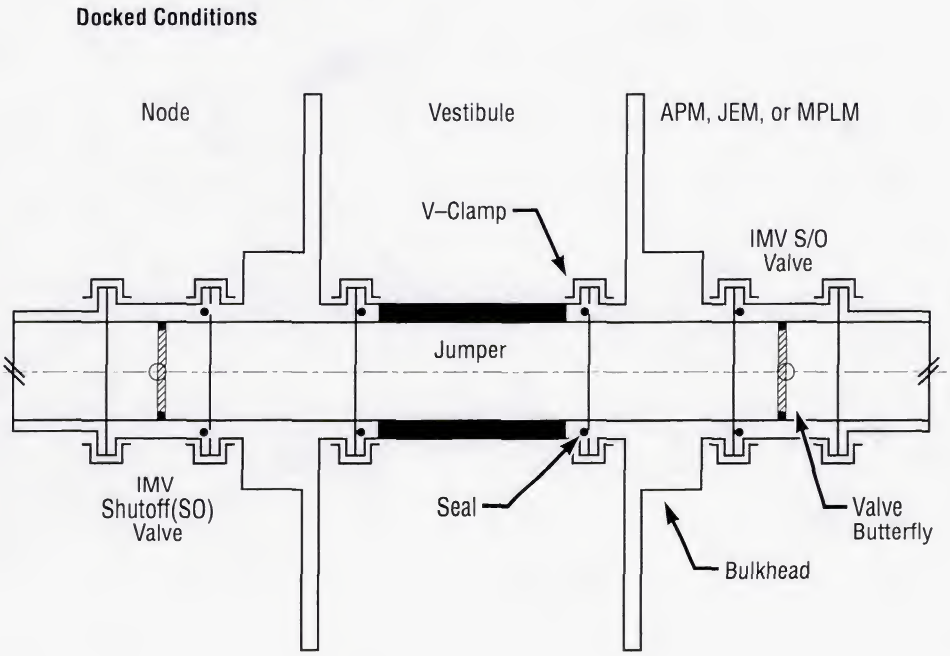


FIGURE 145.—IMV interface connection with Node 2.

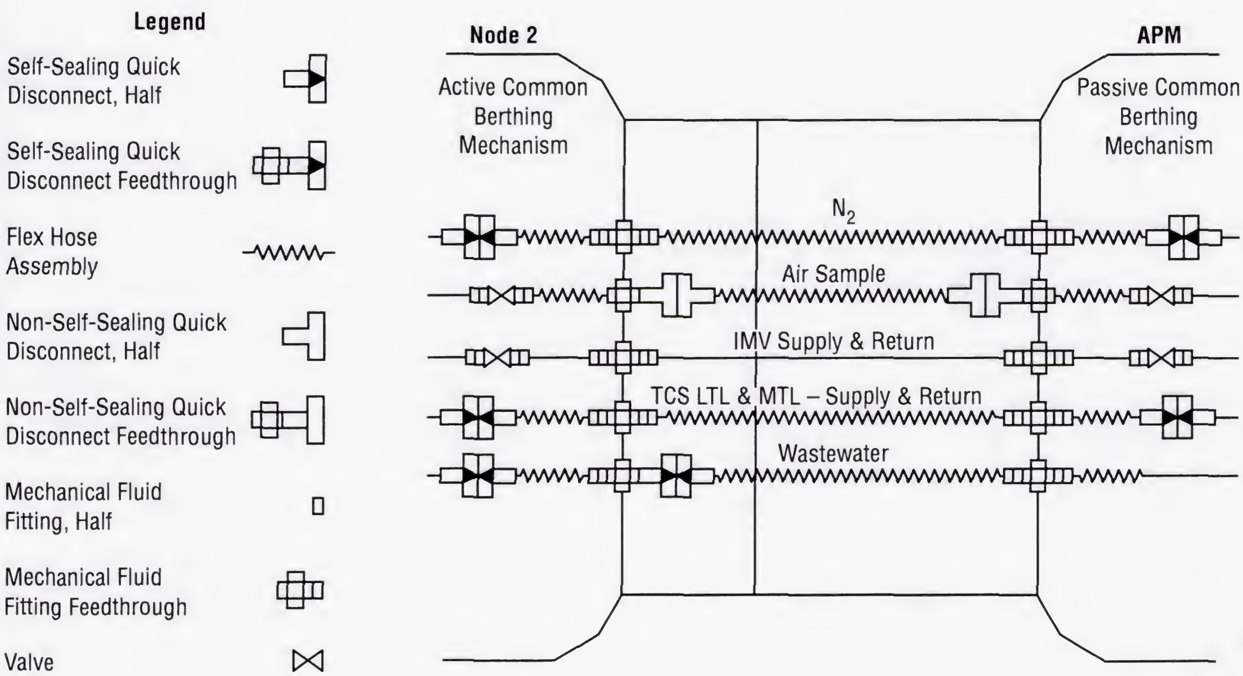


FIGURE 146.—APM fluid interfaces with the USOS.

TABLE 36.—*APM/USOS interfaces and conditions.*

Interface	Conditions
Power	Two Power Feeds of 12.5 kW Each, 120 to 126 Vdc
Heat Rejection	Moderate-Temperature HX Maximum Heat Load of 22 kW Low-Temperature HX Maximum Heat Load of 7 kW Total Heat Load of 22 kW Moderate-Temperature HX Water Side: • Outlet Temperature: 12.8 to 18.3 °C (55 to 65 °F) • Inlet Temperature ≤50 °C (122 °F) Low -Temperature HX Water Side: • Outlet Temperature: 0.6 to 5.6 °C (33 to 42 °F) • Inlet Temperature: 12.8 to 18.3 °C (55 to 65 °F) Moderate-Temperature HX Maximum Flowrate: 1,360 kg/hr (2,998 lb/hr) Low-Temperature HX Maximum Flowrate: 610 kg/hr (1,345 lb/hr)
IMV Heat Load	220 W Sensible, 0 W Latent
Venting	Pressure Range 1×10^5 to 1.3×10^{-1} Pa (14.7 to 1.9×10^{-5} psia) Process Gases
Air Exchange	Air Supply: • Flowrate: 229 to 280 m^3/hr (135 to 165 cfm) • Temperature: 17 to 28 °C (63 to 82 °F) • Cleanliness Level: Class 100,000 Air Return: • Flowrate: 229 to 280 m^3/hr (135 to 165 cfm) • Temperature: 18 to 29 °C (64.4 to 84.2 °F) • Cleanliness Level: Class 100,000
N_2	Mass Flowrate: 0 to 2.72 kg/hr (0 to 6.0 lb/hr) Pressure: • Regulated: 6,200 to 8,270 hPa (90 to 120 psia) • Maximum Design Pressure: 13,780 hPa (200 psia) Temperature: 18 to 27 °C (64 to 81 °F)
Atmosphere Sampling	Flowrate: 0 to 0.64 L/min (0 to 39 in^3/min) Pressure: 957 to 1,027 hPa (13.9 to 14.9 psia) Temperature: 16 to 37 °C (61 to 99°F)
Condensate Water Return	Mass Flowrate: 1.4 kg/hr (3.1 lb/hr) Continuous, 3.2 kg/hr (7 lb/hr) Maximum Pressure (1): 1,380 to 2,070 hPa (20 to 30 psia) Temperature: 4.5 to 43 °C (40 to 109 °F) Particulate Filtration: 100 μm Free-Gas Level: 0 to 10 Percent by Volume (1) The APM delivers the maximum flowrate for any value of the interface pressure up to the maximum.

TABLE 37.—*IMV supply and return at the APM/USOS interface.*

Parameter	Range
Supply Pressure Drop (between Node 2 and the IMV connector at the APM bulkhead) at 280 m^3/hr (165 scfm)	132 Pa (0.53 in H_2O)
Return Pressure Drop (between the IMV connector at the APM bulkhead and Node 2) at 280 m^3/hr (165 scfm)	95 Pa (0.38 in H_2O)
Temperature	18 to 29.5 °C (65 to 85 °F)
Dewpoint	4.4 to 15.6 °C (40 to 60 °F)
IMV Flowrate	229 to 280 m^3/hr (135 to 165 scfm)
Total Pressure—Nominal (1)	95.8 to 102.7 kPa (13.9 to 14.9 psia)
ppO_2 (1)	19.5 to 23.1 kPa (2.83 to 3.35 psia)
$ppCO_2$ (1)	Cabin Air
RH	25 to 70 Percent
Trace Contaminants (2)	Cabin Air
Microbial Count	0 to 1,000 CFU/m^3 (0 to 28 CFU/ft^3)
Particulates >0.5 µm	<3,500,000 PC/m^3 (<100,000 PC/ft^3)
Sensible Heat Load (3)	0 to 400 W
Latent Heat Load (3)	0 to 200 W

Notes:
(1) Atmospheric composition in the APM is controlled by the USOS.
(2) Trace contaminants in the APM are controlled by the USOS according to NHB 8060.1, appendix D, "Flammability, Odor, and Offgassing and Compatibility Requirements and Test Procedures for Materials in Environments that Support Combustion."
(3) Used for THC sizing.

TABLE 38.—*Atmosphere sample line condition at the APM/USOS interface.*

Parameter	Range
Pressure	95.8 to 102.3 kPa (13.9 to 14.9 psia)
Temperature	16 to 37 °C (61 to 99 °F)
Flowrate	0.1 to 0.6 L/min (100 to 600 scfm)
APM Maximum Pressure Loss	1.03 kPa (0.15 psi)
Volume of Gas in Line (Maximum)	TBD m^3
Particle Filter Mesh Size	2 µm
Sample Line Material	Stainless Steel

2.3.2 JEM Interconnections

The JEM fluid interfaces are shown schematically in figure 147. The interfaces and their conditions are listed in table 39. Most of the vestibule jumpers are the same as for the APM. The condensate from the CHX is delivered to the USOS via a dedicated condensate return (wastewater) line. The conditions in this line at the interface with the USOS are also listed in table 39.

2.3.3 MPLM Interconnections

The fluid interfaces of the MPLM are shown schematically in figure 148. The interfaces and their conditions are listed in table 40. The vestibule jumpers are the same types as for the APM interconnections. The locations of the MPLM interface connections are shown in Figure 149.

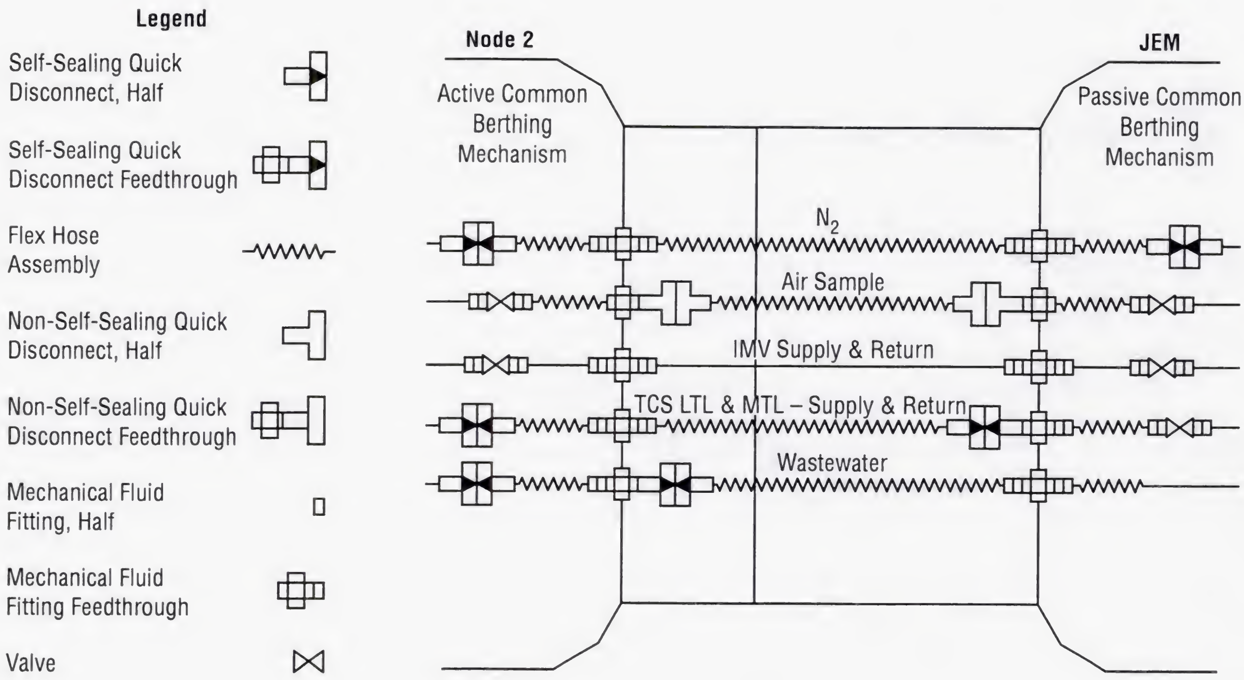


FIGURE 147.—JEM fluid interfaces with the USOS.

TABLE 39.—*JEM interfaces with the USOS.*

ECLSS Interface	Flowrate	Temperature	Notes
IMV Supply	229 to 246 m^3/hr (135 to 145 cfm)	18.3 to 29.4 °C (65 to 85 °F)	Maximum Node-Side Pressure Loss = 9.7 mm (0.38 in) H_2O Pressure = 0.96 to 1.05 bar (13.9 to 15.2 psia)
IMV Return	229 to 246 m^3/hr (135 to 145 cfm)	18.3 to 29.4 °C (65 to 85 °F)	Maximum JEM-Side Pressure Loss = TBD in H_2O; Maximum JEM-Side Heat Removal = ± 220 W; Pressure = 0.96 to 1.05 bar (13.9 to 15.2 psia)
Condensate Water Return	0 to 3.2 kg/hr (7 lb/hr) 0 to 13.6 kg/hr (0 to 30 lb/hr) peak (for up to 12 min)	4.4 to 45 °C (40 to 113 °F)	H_2O Pressure Range = 0 to 0.55 bar (55 kPa, 8 psig) above ambient; Maximum Design Pressure = 3.1 bar (310 kPa, 45 psia); Free-Gas Volume at 4.4 °C (40 °F) and 142.7 kPa (20.7 psia) = 0 to 10 percent Maximum Particulate Size = 100 μm
N_2	0.27 kg/hr (0.6 lb/min)	18.3 to 29.4 °C (65 to 85 °F) (except during initial startup)	Nominal Pressure Range = 621 to 827 kPa (90 to 120 psia) Maximum Design Pressure = 1,378 kPa (200 psia)
Atmosphere Sampling	0 to 0.6 L/min (600 scc/min, 0.02 cfm, 35 in^3/min)	17.2 to 42.8 °C (63 to 109 °F)	Pressure Range = 75.8 to 104.8 kPa (11.0 to 15.2 psia) Maximum Pressure Loss = TBD at 0.6 L/min (0.02 cfm) JEM Line Gas Volume = TBD

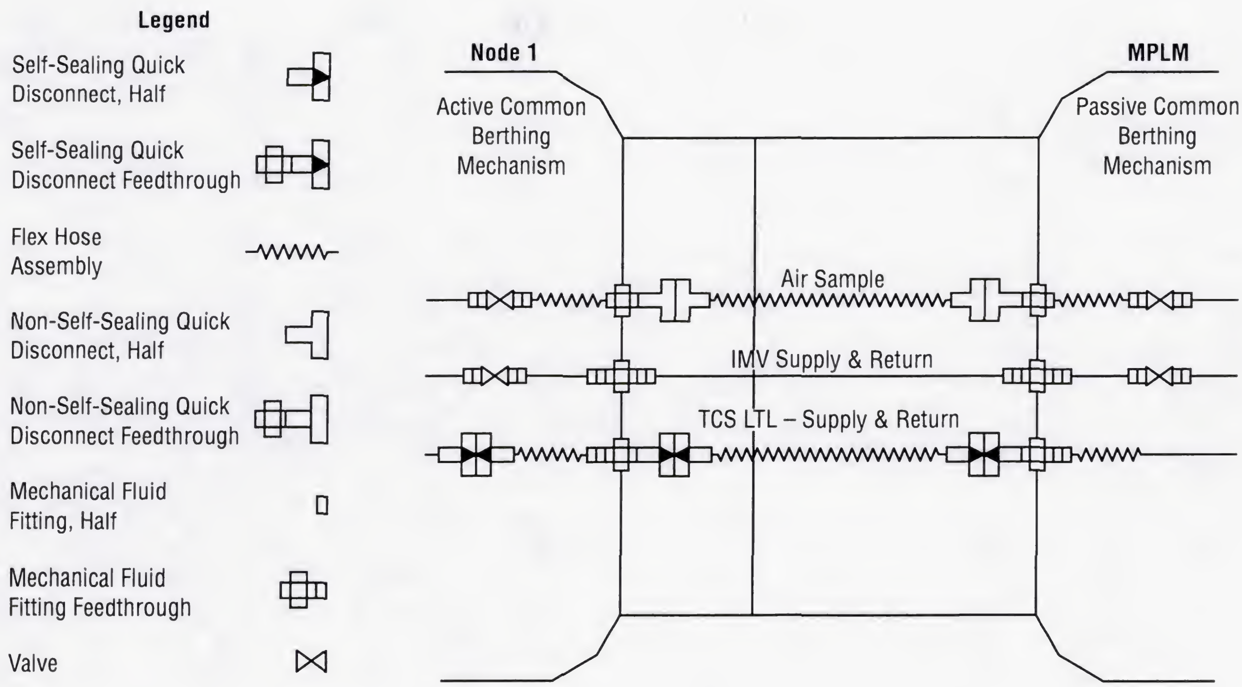


FIGURE 148.—MPLM fluid interfaces with the USOS.

TABLE 40.—*MPLM/USOS interface conditions.*

ECLSS Interface	Flowrate	Temperature	Notes
IMV Supply	229 to 246 m^3/hr (135 to 145 cfm)	7.2 to 29.4 °C (45 to 85 °F)	Pressure from 0.9 to 1.03 bar (96 to 105 kPa) (13.9 to 15.2 psia)
IMV Return	229 to 246 m^3/hr (135 to 145 cfm)	18.3 to 29.4 °C (65 to 85 °F)	Pressure from 0.9 to 1.03 bar (96 to 105 kPa) (13.9 to 15.2 psia)
Atmosphere Sample	0 to 400 scc/min	18.3 to 29.4 °C (65 to 85 °F)	Pressure from 0.9 to 1.03 bar (96 to 105 kPa) (13.9 to 15.2 psia)

2.4 Logistics Resupply

As much as feasible, regenerable technologies are used for the ECLSS. Some expendable components are used, however, and these must be resupplied. The expendable items and replaceable components are listed in table 41.

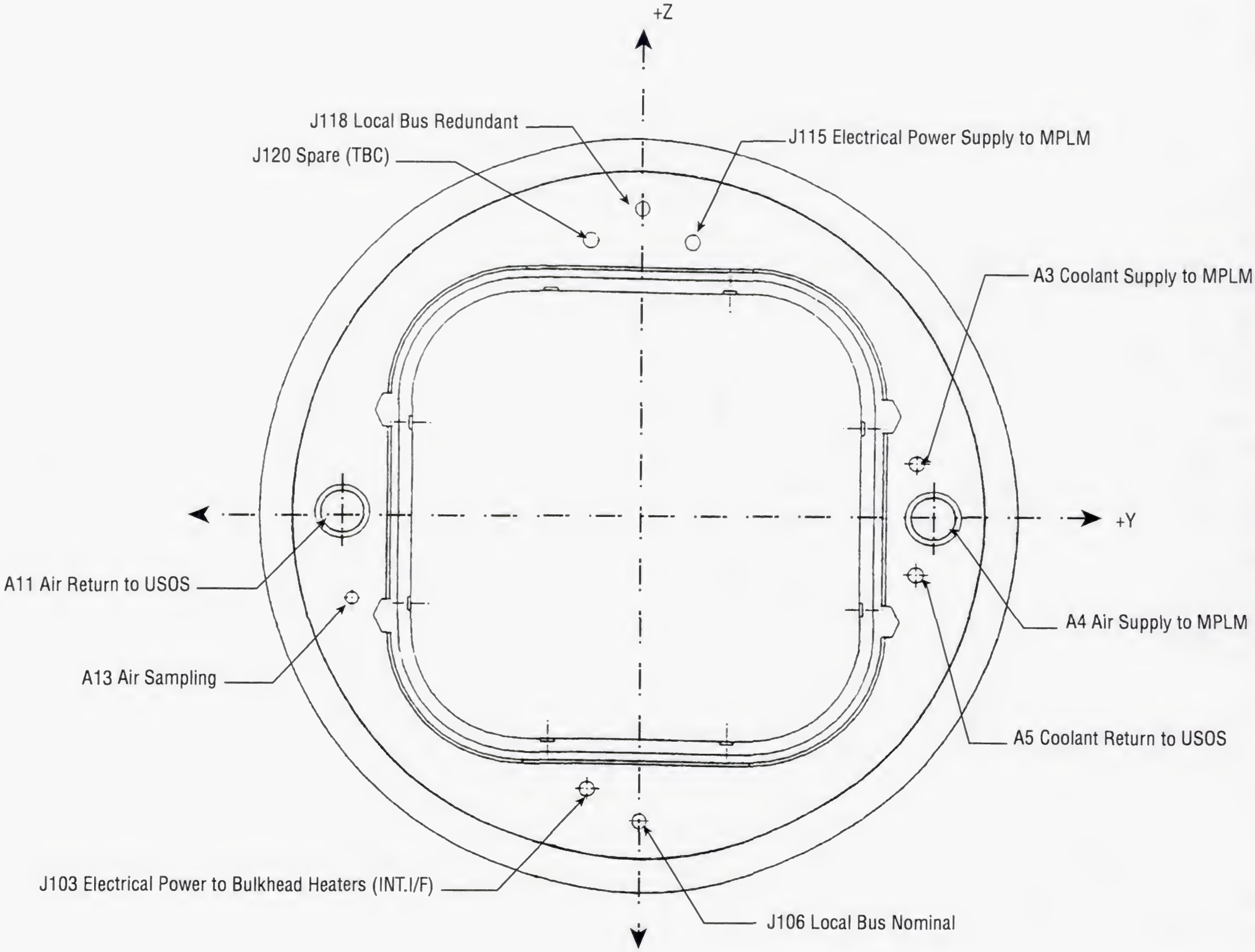


FIGURE 149.—MPLM interface connections.

Table 41.—*ECLS logistics resupply.*

ORU/Component	Mass (kg)	Mass (lb)	Power Consump-tion (W)	Design Life	Replacement Period	Notes
Attached Pressurized Module (APM)						
Atmosphere Control and Supply (ACS)						
Total Pressure Sensor	0.34	0.75	248 mW			
DA	2.9	6.4	195 for heater and 14.85 (peak) for motorized valve			
PPRA	2.31	5.09	14.85 peak			
NPRA	0.98	2.16				
MPEV						Same as USOS
Vent and Relief Assembly						
Temperature and Humidity Control (THC)						
Atmosphere Temperature Sensor	50 g	0.11				
CCAA						Same as USOS
HEPA filters						
Fan assembly	26	57				
Cabin Air Diffuser						
AAA						Same as USOS
Atmosphere Revitalization (AR)						
Atmosphere Sample Line:						
Sample Line Shutoff Valve	1.4	3.1	20 peak			
Sample Line Filter	0.15	0.33				
Fire Detection and Suppression (FDS)						
Smoke Detector	1.02	2.25				Same as USOS
PFE						Same as USOS
PBA						Same as USOS
Emergency Warning Panel						
Vacuum Services (VS)						
Low-Range P Sensor						
High-Range P Sensor						
Manual Valves						
JEM						
Atmosphere Control and Supply (ACS)						
In the PM:						
O_2/N_2 Control Unit:						
• Solenoid/Manual Valves						
• Total Pressure Sensors	0.34	0.75	248 mW			2 sensors
Vent and Relief Assembly						Same as USOS
Motor/Manual Valves						2 each
O_2/N_2 Distribution						
• Distribution Lines						
• Manual Valve						
• Flow Orifice						
MPEV's						2 valves, Same as USOS
PPRA		2.31	5.09			Same as APM
NPRA's						2 valves, Same as APM

TABLE 41.—*ECLS logistics resupply (continued).*

ORU/Component	Mass (kg)	Mass (lb)	Power Consump-tion (W)	Design Life	Replacement Period	Notes
In the ELM–PS:						
Vent and Relief Assembly						
• Motor/Manual Valves						2 each
• Total Pressure Sensors						2 sensors
O_2/N_2 Distribution:						
• Distribution Lines						
• Solenoid/Manual Valve						
• Flow Orifice						
MPEV						Same as USOS
PPRA						Same as APM
NPRA						2 valves, Same as APM
Temperature and Humidity Control (THC)						
Atmosphere Temperature Sensor						
CCAA						
Cabin Fan						Same as USOS
Liquid sensor						Same as USOS
AAA						Same as USOS
IMV Fan						Same as USOS
IMV Valve						Same as USOS
Atmosphere Revitalization (AR)						
PM:						
• Solenoid/Manual Valve						
• Manual Valve						2 Valves
• Sample Lines						
ELM–PS:						
• Solenoid/Manual Valve						
• Sample Lines						
HEPA Filters						
Fire Detection and Suppression (FDS)						
PM:						
• SD	1.02	2.25				15 Detectors. Same as USOS
• PFE	5.0	11.0				2, Same as USOS
• PBA						2, Same as USOS
• Fire Panel						29 Panels
ELM–PS:						
• SD	1.02	2.25				2 Detectors, Same as USOS
• PFE						1, Same as USOS
• PBA						2, Same as USOS
• Fire Panel						2 Panels
Vacuum Services (VS)						
Low-Range P sensor						
High-Range P sensor						
Manual valves						
Latching Solenoid Valve						
Normally-Closed Solenoid Valve						
Manual Valve						
Temperature Sensor						
Tanks						

TABLE 41.—*ECLS logistics resupply (continued).*

ORU/Component	Mass (kg)	Mass (lb)	Power Consump-tion (W)	Design Life	Replacement Period	Notes
Experiment Airlock						
Vacuum Pump						
Fan						
Dehydrator						
Solenoid Valve						
Manual Valve						
Filter						
Flow Restrictor						
MPLM						
Atmosphere Control and Supply (ACS)						
Total Pressure Sensor						Same as USOS
Depressurization Assembly	2.9	6.4				Same as APM
Intermodule Fluid Connectors						
NPRA	0.98	2.16				4 NPRA's
PPRA	2.31	5.1	14.85 peak			2 PPRA's Same as USOS
MPEV						Same as USOS
Atmosphere Revitalization (AR)						
Intermodule Fluid Connector						
Sample Line Shutoff Valve	1.4	3.1	20 peak			
Sample Line Filter	0.15	0.33				
Temperature and Humidity Control (THC)						
Diffusers						Same as APM
Temperature Sensors						
Cabin Fan Assembly						
Cabin Outlet Grids						
Cabin Fan Assembly						Same as USOS
Cabin Fan Assembly Inlet Muffler						
Grilles						
IMV Shutoff Valve	5.34	11.75	0.15 (standby) 20 (max)	3,750 cycles		
Atmosphere Revitalization (AR)						
Vent and Relief Valve Assembly						
Fire Detection and Suppression (FDS)						
SD						Same as USOS
PFE	5.0 dry mass	11.0 dry mass				Arde, Inc. Same as USOS
PBA						Same as USOS

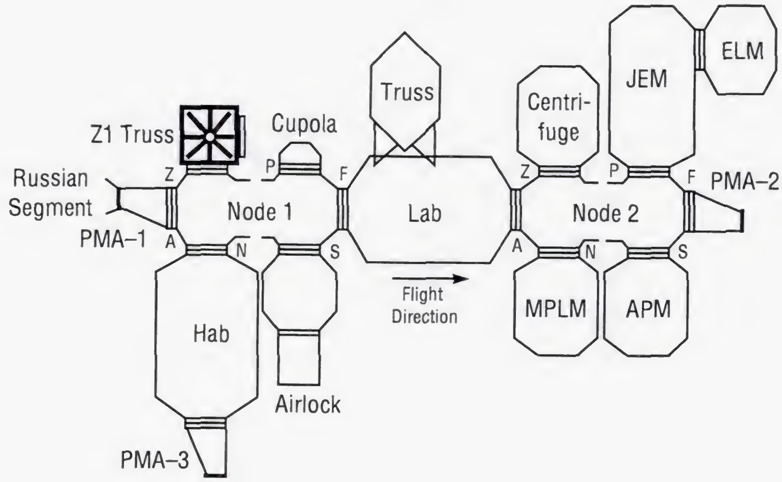
3.0 ECLS Technologies

The technologies that perform the ECLS functions in the APM, JEM, and MPLM are described in this section. Under each functional category, the specific capabilities are described for each segment.

3.1 Atmosphere Control and Supply (ACS)

The ACS subsystems in the APM, JEM, and MPLM are shown schematically in figures 150–152, and are described in the following sections for each segment.

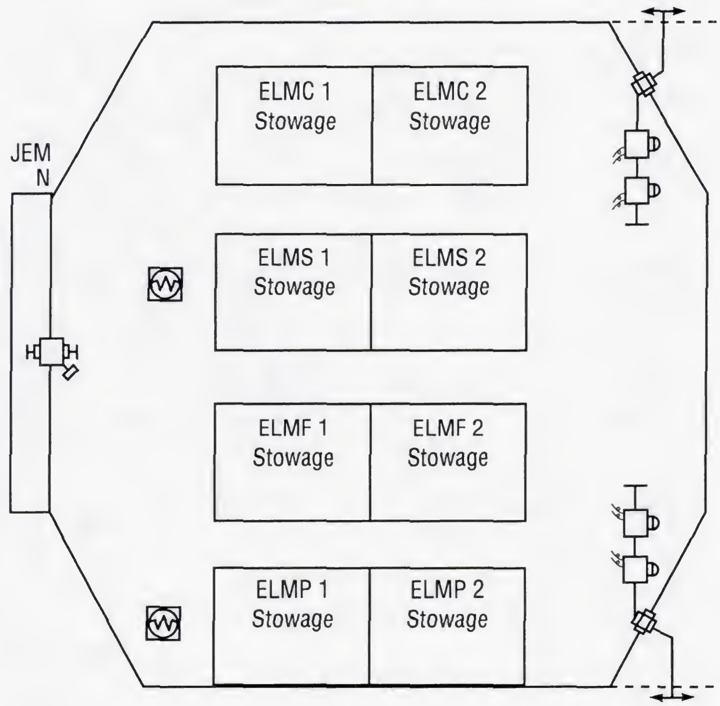
Legend



	Self-Sealing Quick Disconnect, Half		Check Valve
	Self-Sealing Quick Disconnect, Half with Check Valve		Pressure Regulator
	Flex Hose		Relief Valve
	Feedthrough		Tank
	Mechanical Fitting, Half		Manual Valve
	Manual Valve With Manual Interfaces on Both Sides and Fluid Interface		Motor Valve With Position Indication
	Pressure Sensor		Motor Valve With Manual Overide and Position Indication
	Solenoid Valve With Manual Overide and Position Indication		Pump
	Non-Propulsive Vent		Burst Disk
CPS	Cabin Pressure Sensor		Diffuser
VAJ	Vacuum Access Jumper		Orifice
FC	Firmware Controller		Heater
PCP	Pressure Control Panel Subassembly		Temperature Sensor
VRV	Vent Relief Subassembly		O_2
PCA	Pressure Control Assembly		N_2
NIA	Nitrogen Interface Assembly		O_2 Recharge
			N_2 Recharge

FIGURE 150.—ACS subsystems.

JEM–ELM



JEM—PM

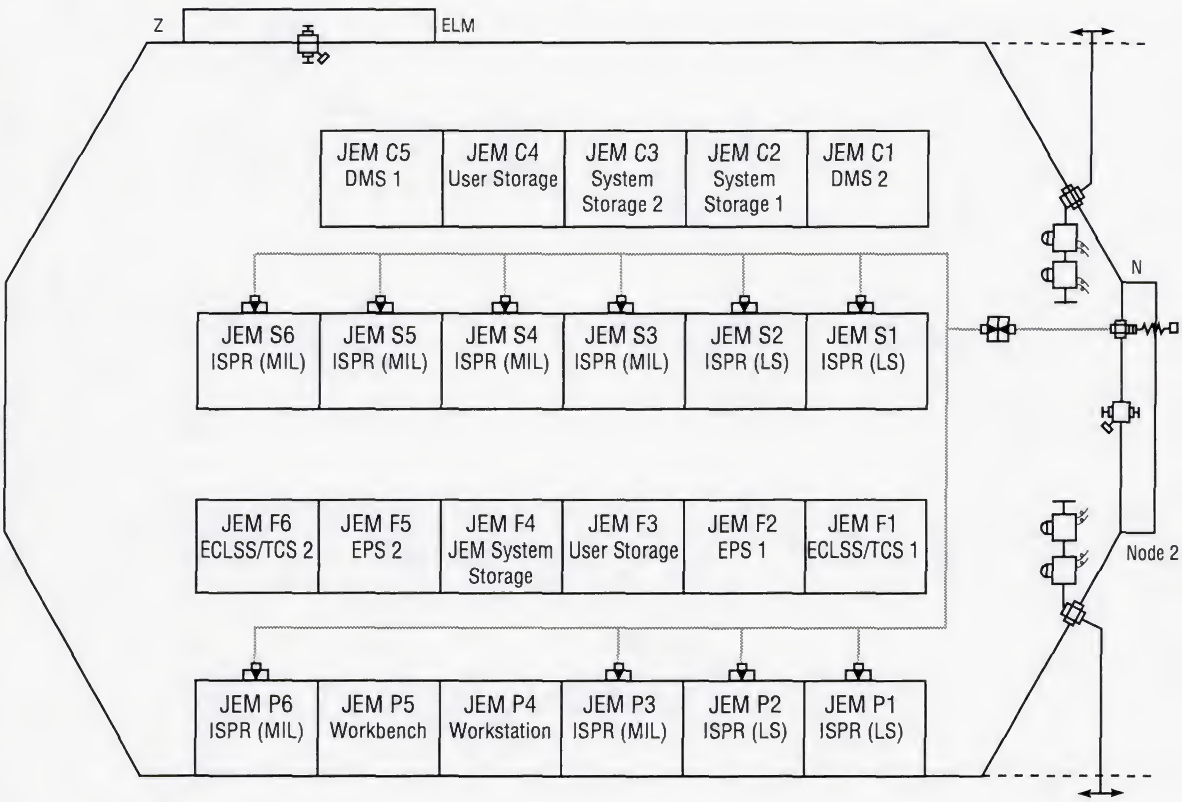


FIGURE 151.—ACS subsystems (continued).

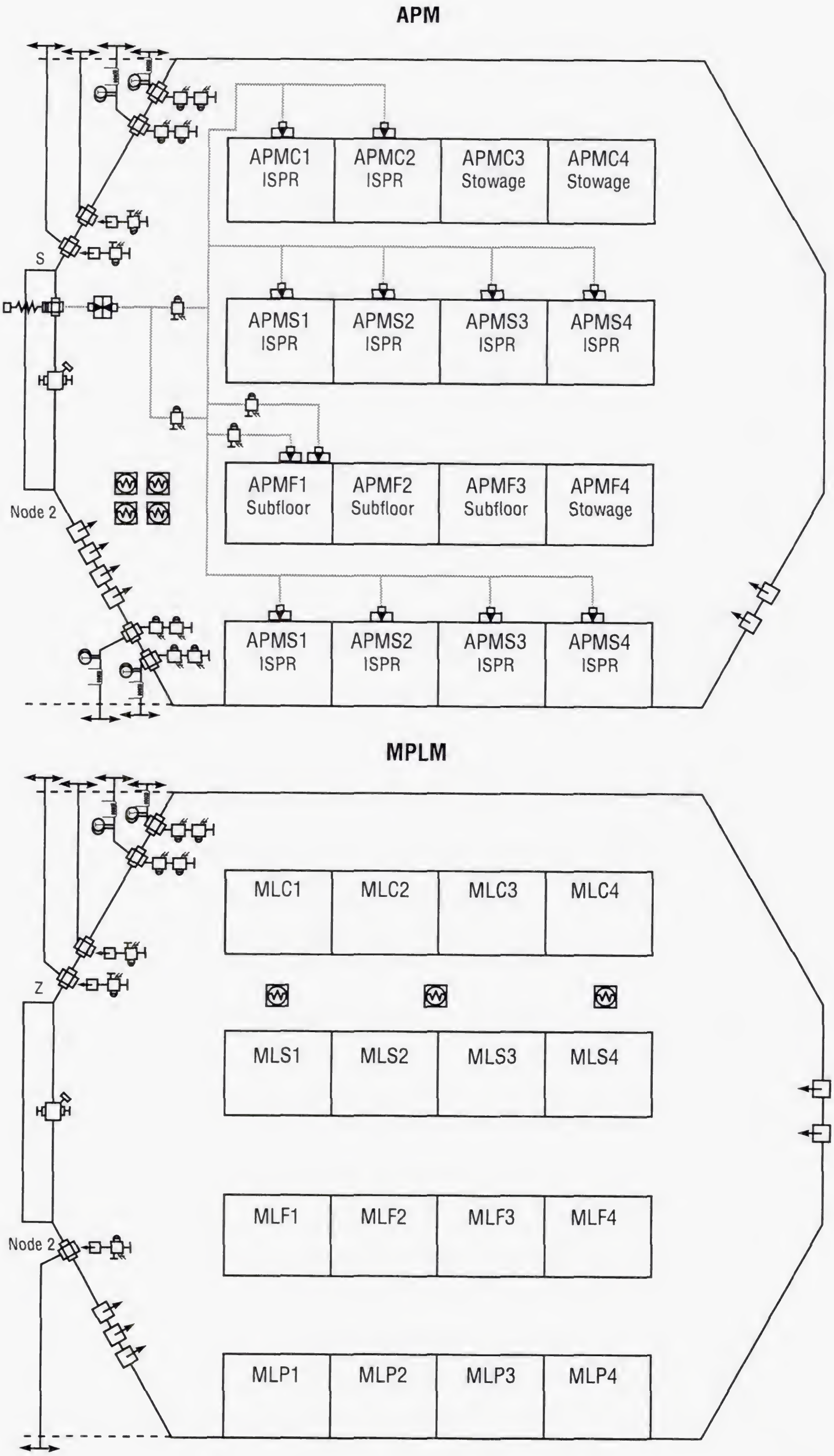


FIGURE 152.—ACS subsystems (continued).

3.1.1 APM ACS

The ACS equipment that is in the APM is described below.

3.1.1.1 Control Total Atmospheric Pressure

Total atmospheric pressure is monitored in the APM. Negative pressure relief is also provided in the APM. Other ACS functions such as adding N_2 are provided by the USOS or RS. There is no pressure control panel in the APM.

3.1.1.1.1 Monitor Total Atmospheric Pressure

The total atmospheric pressure sensor, shown in figure 153, is a standard, bonded-foil strain gauge sensor. The basic principle of operation is to derive an output resulting from a pressure induced imbalance in a four-active-arm Wheatstone bridge. The rate of pressure change (dP/dt) is not calculated in the APM. Instead, the total pressure is monitored by the crew who determine if there is excessive pressure change. The characteristics of the total pressure sensor are listed in table 42.

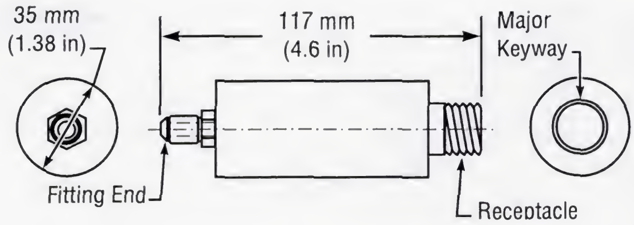


Figure 153.—APM total pressure sensor.

3.1.1.1.2 Negative Pressure Relief Assembly (NPRA)

The NPRA's are derived from the Carleton NPRA's used on the space shuttle, shown in figure 154. Each assembly consists of a pneumatic valve designed to open automatically when external pressure exceeds internal pressure, and to prevent the escape of module air when there are normal pressure conditions inside the module.

The pneumatic valve is of primary poppet construction and incorporates a captive redundant seal cover which provides assurance against air outflow resulting from a primary poppet failure. The detent spring offsets the cover assist spring force to protect against premature cover deployment due to launch vibration, etc. The cover spring ensures that the cover opens fully when actuated to assure unimpeded airflow through the valve.

Table 42.—*APM total pressure sensor characteristics.*

Sensor Characteristics	Metric Units	U.S. Units
Envelope	35 mm diameter × 117 mm length	1.38 in diameter × 4.61 in length
Mass	0.34 kg	0.75 lb
Range	0 to 138 kPa	0 to 20 psia
Accuracy	± 0.02 percent full scale	± 0.02 percent full scale
Operating Environment:		
Temperature	–1.1 to 60 °C	30 to 140 °F
Pressure	0 to 110.3 kPa	0 to 16 psia
Power Consumption	248 mW	248 mW
Power	28 Vdc	28 Vdc
Input Voltage	15 ±1.8 Vdc	15 ±1.8 Vdc
Data	0 to 5 Vdc (analog)	0 to 5 Vdc (analog)
Output signal	4 mA at 0 kPa to 20 mA at 110.3 kPa, linear	4 mA at 0 psia to 20 mA at 16 psia, linear

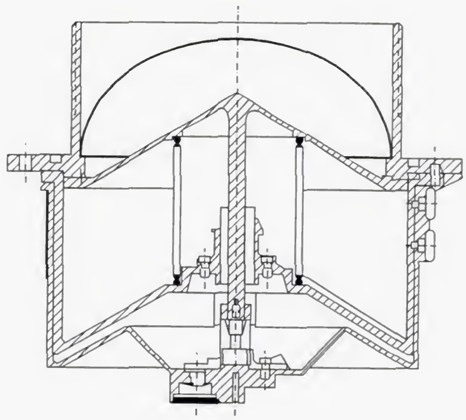


FIGURE 154.—NPRA.

The main physical and performance characteristics of the underpressure relief assembly are:

- Dimensions
  - 178 mm length by 175 mm diameter (7.0 in length by 6.9 in diameter)
- Mass
  - 0.98 kg (2.16 lb)
- Nominal airflow rate
  - 0.54 kg/sec at 3.4 kPa ΔP and 21 °C (1.19 lb/sec at 0.5 psid and 70 °F)
- External leakage
  - 0.1 scc/min
- Minimum cracking pressure
  - 17.2 hPa (0.25 psid)
- Full flow at
  - 34.5 hPa (0.5 psid)
- Maximum flowrate
  - 0.54 kg/hr (1.19 lb/hr).

A functional schematic of the NPRA is shown in figure 155. The location of the NPRA is shown in figure 142. Negative pressure is limited to be less than 34.5 hPa (0.5 psid). Five vent lines are sufficient to meet the requirement and there is one redundant vent line, so the NPRA is one-failure tolerant with regard to failure to open.

3.1.1.1.3 N_2 Distribution

N_2 is supplied from the USOS for rack–mounted payloads and subsystems in the APM and is distributed to each standoff for use by payloads and subsystems.

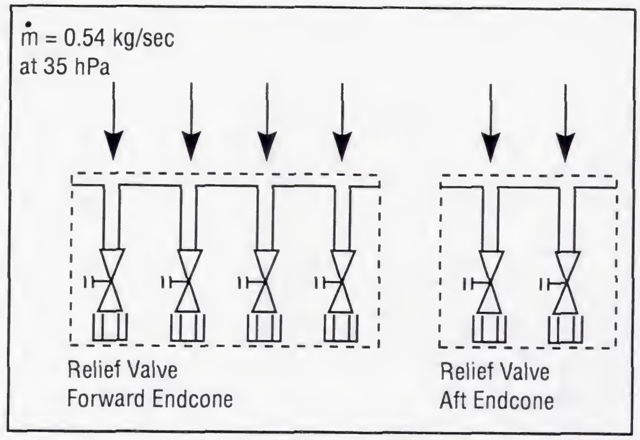


FIGURE 155.—APM NPRA functional schematic.

3.1.1.2 Control Oxygen Partial Pressure

This capability is not required in the APM and is provided by the USOS or RS. The ppO_2 is, however, monitored in the APM using an electrochemical sensor.

The major constituent composition of the atmosphere (including O_2) is monitored by the USOS through the SDS that consists of a sample line for delivering atmosphere samples to the USOS, a shutoff valve, and a filter.

A functional schematic of the sample line is not presently available. This line includes a filter screen and two valves in series (one is redundant to provide one failure tolerance). The pressure loss in the APM sampling line is ≤10.3 hPa (0.15 psid) at 600 scc/min. The particle filtration level is 2 µm. The SDS is described further in chapter II, section 3.3.2.1.4.

3.1.1.3 Relieve Overpressure

The PPRA, shown schematically in figure 156, ensures that the pressure differential does not exceed 1,048 hPa (15.2 psid) during both berthed and unberthed conditions. As shown in figure 142, there are two vent lines. One line is sufficient to meet the requirement and the other line is redundant, so the PPRA is one- failure tolerant with regard to failure to open. Each vent line has a pneumatic valve downstream of a motorized valve (that has a position indicator) in series with a manual over-ride (shown in fig. 157), so each line is one-failure toler-ant with regard to failure to close. The performance characteristics of the valves are:

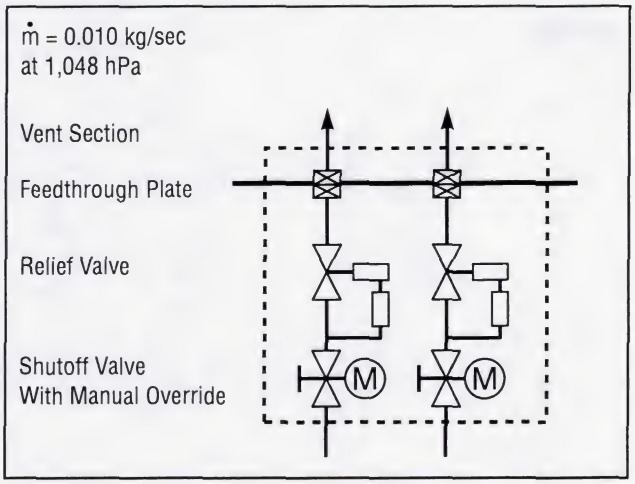


FIGURE 156.—PPRA functional schematic.

- Minimum cracking pressure
  – 1,021 hPa (14.8 psid)
- Minimum reseat pressure
  – 1,004 hPa (14.56 psid)
- Full flow pressure
  – 1,046 hPa (15.17 psid)
- Maximum flowrate
  – 68 kg/hr (150 lb/hr).

The PPRA also includes a debris screen, a non-propulsive vent, and a support flange. The pneumatic valve provides automatic positive pressure relief and the motorized valve is used to disable or re-enable the pneumatic valve and to provide single-failure tolerance in case the pneumatic valve fails to close or it opens when not needed.

The PPRA's are derived from the Carleton PPRA's used in the Spacelab. Each assembly consists of a mechanical pressure relief valve and a motor-driven valve (normally open) connected in series and arranged in a common valve bore. Modifications for use on the *ISS* include modifying the valve spring to have a cracking pressure of 102.0 kPa (14.8 psia) and full-flow pressure of 104.8 kPa (15.2 psia). The relief valve is a poppet-type, pressure compensated by a bellows, and incorporates an electrically operated closing override butterfly valve. The motor-driven valve consists of a 28 Vdc brush-type motor, a valve position indicator, and a butterfly valve. A captive-debris screen on the internal side of the assembly and a filter screen on the bulkhead side of the assembly provide protection from foreign material.

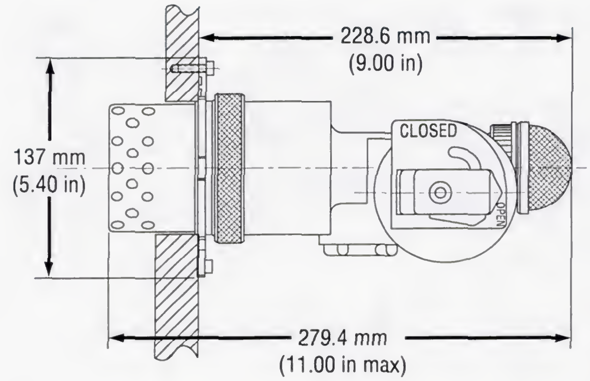


FIGURE 157.—Positive pressure relief valve.

The main physical and performance characteristics of the PPRA are:

- Dimensions
  – 279 by 203 by 127 mm (11 by 8 by 5 in)
- Mass
  – 2.31 kg (5.09 lb)
- Nominal airflow rate
  – 0.018 kg/sec at 104.8 kPa ΔP and 21.1 °C
  – (0.040 lb/sec at 15.2 psid and 70 °F)
- External leakage
  – 0.1 scc/min
- Power consumption
  – 14.85 W peak for motorized valve.

3.1.1.4 Equalize Pressure

The pressure differential between adjacent, isolated modules is equalized by means of the MPEV mounted in the hatch between the modules. The APM MPEV is identical with the USOS MPEV, described in chapter II, section 3.1.4.

3.1.1.5 Respond to Rapid Decompression

The differential pressure of depressurization, repressurization, and the depressurized condition can be tolerated by the equipment and structure without resulting in a hazard or failure propagation. The response to rapid decompression is to evacuate the module and seal the Node 2 hatch to the APM, as described in section 6.6. After any necessary repairs are made, the APM is repressurized by allowing atmosphere to flow from Node 2 into the depressurized module through the Node 2 MPEV,

described in chapter II, section 3.1.4. This manually operated valve allows controlled airflow between modules and supports manual atmosphere sampling equipment as well. The MPEV is identical to the MPEV's for the USOS, and is manually actuated from either side of a hatch. The gases necessary to repressurize the APM, and any other supplies or equipment required to respond to rapid decompression, are provided by the USOS.

3.1.1.6 Respond to Hazardous Atmosphere

The initial response is for the crew to don PBA's, which have a 15 min supply of bottled O_2 or air. There are two PBA's in the APM. When initiated by the crew or ground control the APM atmosphere can be vented to space to achieve a pressure of less than 2.8 kPa (0.4 psia) within 24 hr. The APM can be repressurized via the MPEV from space vacuum to a total pressure of 95.8 to 98.6 kPa (13.9 to 14.3 psia) and a ppO_2 of 16.4 to 23.1 kPa (2.38 to 3.35 psia) within 75 hr with O_2 and N_2 from the USOS as specified in SSP 41150.

3.1.1.6.1 Depressurization Assembly (DA)

The DA provides atmosphere venting on request in order to:

- Relieve overpressurization in a module.
- Vent a module in response to a fire or release of toxic chemicals from a payload.
- Discharge air for fine cabin pressure adjustment.

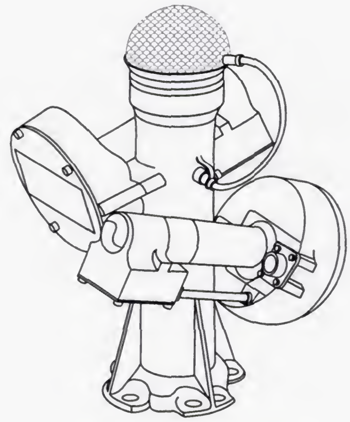
The DA consists of two motor-driven valves with manual override:

- Isolation valve to provide vent isolation and safing.
- Vent valve to provide a vent to space.

Two depressurization assemblies provide sufficient capability to allow reducing the ppO_2 to < 6.9 kPa (1.0 psia) within 10 min, to extinguish a fire. The two valves in series in each assembly provide single failure tolerance in case of a failure to close or an unwanted activation. The motorized valves are normally unpowered.

3.1.1.6.1.1 DA Design

The depressurization capability consists of two DA's, each including a debris screen, a non-propulsive vent, a heater (dedicated thermistor), support flange, and two motorized valves arranged in series and normally closed. Each valve, shown in figure 158, includes a position sensor. As shown in the functional schematic (fig. 159), there are four non-propulsive vents.



Cabin Pressure Bleed Valve

FIGURE 158.—APM and MPLM depressurization assembly.

The heaters are installed on the external side of the DA, close to the vent. The function of the heaters is to avoid ice formation on the external surfaces of the assemblies, due to moisture in the atmosphere being released during depressurization, and possible blockage of the vent. The vent is long enough to accommodate placing the heaters in this location. The heaters use 120 Vdc power. Each vent line has two motorized valves in series, so each vent line is one-failure tolerant with regard to failure of a valve to close.

The main physical and performance characteristics of the DA are:

- Dimensions
  - 250 by 140 by 110 mm (9.8 by 5.5 by 4.3 in)
- Mass
  - 2.9 kg (6.4 lb)
- Nominal airflow rate
  - 0.1185 kg/sec at 101.35 kPa and 21.1 °C
  - (0.2613 lb at 14.7 psia and 70 °F)
- Internal leakage
  - 0.1 scc/min
- External leakage
  - 0.1 scc/min
- Power consumption
  - 14.85 W for the motorized valve (peak), 195 W heater.

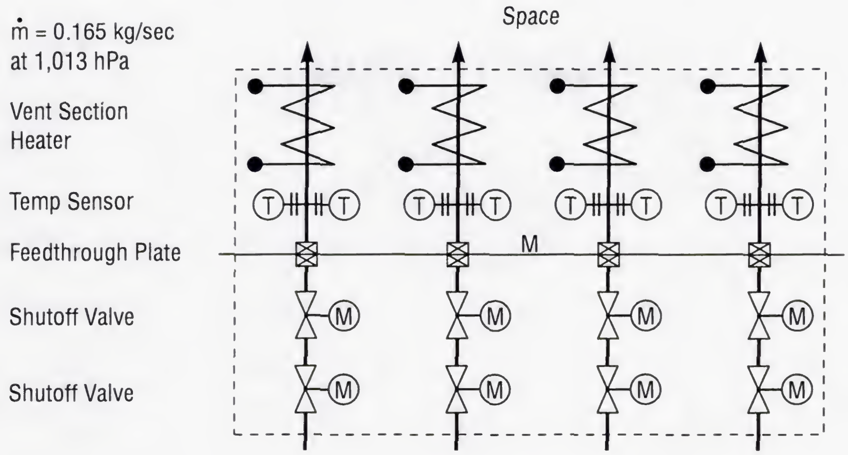


FIGURE 159.—APM depressurization assembly functional schematic.

3.1.1.6.1.2 DA Operation

In operation, a command would be sent by the USOS controller to the module avionics system to open the two normally closed valves in each DA. Heaters on the DA venting devices are controlled via a dedicated redundant electronic unit (heater control unit (HCU)), shown schematically in figure 160, that is mounted external to the APM. The HCU monitors the relevant temperature sensors and commands the heaters.

3.1.1.6.1.3 DA Performance

The heater power required to preclude ice formation is up to 195 W (in the case of maximum humidity and minimum temperature in the atmosphere). The maximum flowrate ($\dot{m}$) is 0.165 kg/sec (0.364 lb/sec) at 1,013 hPa (14.7 psia) and 21 °C (70 °F).

3.1.2 JEM ACS

The ACS equipment that is in the JEM is described below.

3.1.2.1 Control Total Atmospheric Pressure

Total atmosphere pressure is monitored in the JEM. Negative pressure relief is also provided in the JEM. Other ACS functions such as adding N_2 are provided by the USOS or RS. There is no pressure control panel in the JEM.

3.1.2.1.1 Monitor Total Atmosphere Pressure

The total pressure monitoring capability consists of pressure sensors to monitor total pressure for failure detection and isolation purposes. Two sensors are located in the JEM PM and two are located in ELM–PS. The rate of pressure change (dP/dt) is not calculated in the JEM. Instead, the total pressure is monitored by the crew, who determine if there is excessive pressure change.

3.1.2.1.2 Negative Pressure Relief Assembly (NPRA)

The NPRA in the JEM is identical with the NPRA used in the APM and MPLM, described in section 3.1.1.1.2.

3.1.2.1.3 N_2 Distribution

Nitrogen is supplied from the USOS for rack-mounted payloads and subsystems in the PM. The supply is routed to the racks via one supply line in each lower standoff. A side branch from the standoff line serves the ITCS water loop accumulator for pressurization. Motorized isolation valves with manual override control the distribution of N_2.

The N_2 distribution system consists of lines to deliver N_2 to cabin distribution points in the PM. These lines have an inner diameter (ID) of 0.95 cm (3/8 in).

3.1.2.2 Control Oxygen Partial Pressure

This capability is provided by the USOS or RS via IMV.

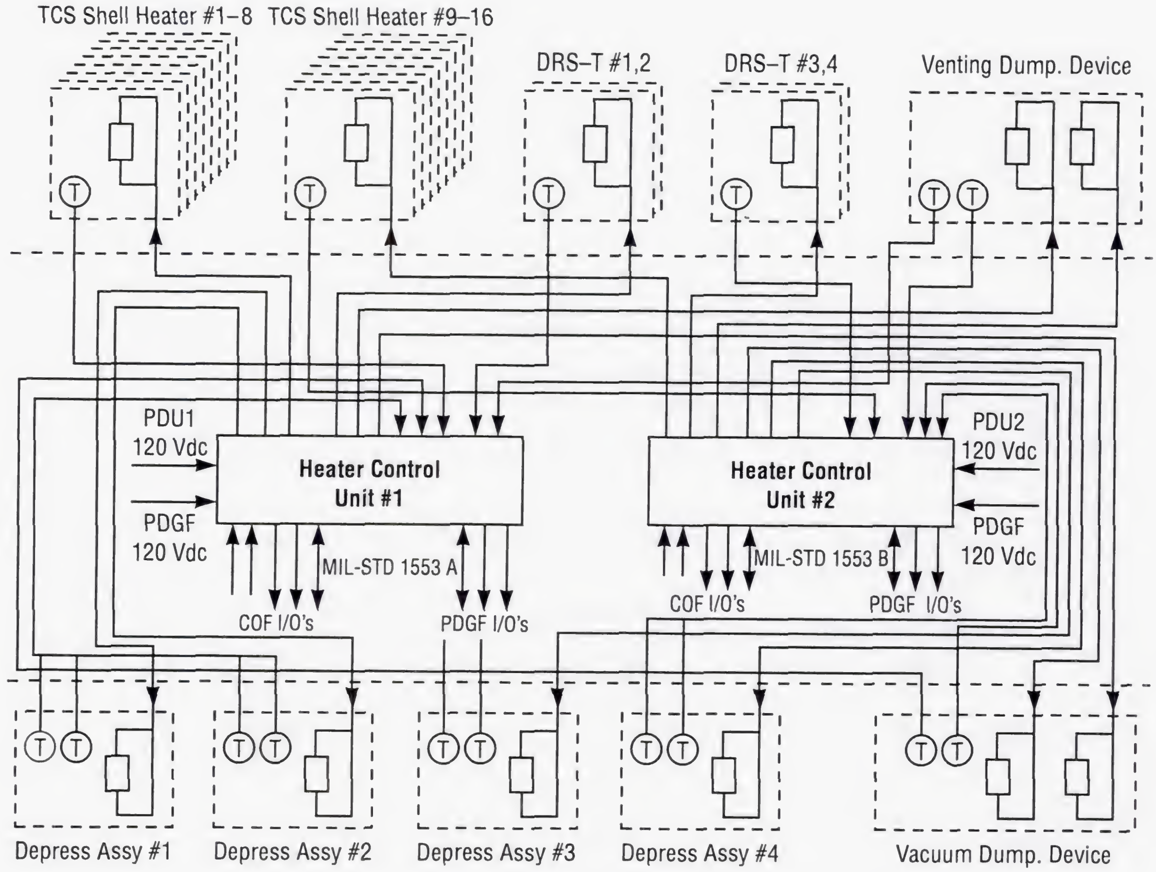


FIGURE 160.—APM heater control functional schematic.

The major constituent composition of the atmosphere (including O_2) is monitored by the USOS through the SDS that consists of a sample line for delivering atmosphere samples to the USOS, a shutoff valve, and a filter.

The SDS performs the following functions and features:

- Supports remote activation/isolation of PM and ELM–PS sampling for ingress/egress.
- Latching solenoid valve with manual override, on/off position, and position switch.
- Supports remote sampling of PM and ELM–PS atmosphere.

The SDS consists of the following components:

- Solenoid/manual sampling valve:
  - One in the PM and one in the ELM
- Manual sampling valve:
  - Two in the PM to isolate sampling to PM and to ELM–PS
  - Manual valve with on/off position and position switch
- Sample delivery lines:
  - PM sample obtained from IMV return duct
  - ELM–PS sample obtained from cabin air return duct
  - 0.32 cm (1/8 in) ID lines.

3.1.2.3 Relieve Overpressure

Atmospheric pressure is maintained to less than the design maximum internal-to-external differential pressure (104.8 kPa (15.2 psid)) by a PPRA. Venting of atmosphere to space does not occur at less than 103.4 kPa (15.0 psid). The JEM PPRA is identical with the APM PPRA described in section 3.1.1.3.

3.1.2.4 Equalize Pressure

The pressure differential between adjacent, isolated modules is equalized by means of the MPEV mounted in the hatch between the modules. The JEM MPEV is identical with the USOS MPEV, described in chapter II, section 3.1.4.

3.1.2.5 Respond to Rapid Decompression

The differential pressure of depressurization, repressurization, and the depressurized condition can be tolerated by the equipment and structure without resulting in a hazard or failure propagation. The response to rapid decompression is to evacuate the module and seal the Node 2 hatch to the JEM, as described in section 6.6. After any necessary repairs are made, the JEM is repressurized by allowing atmosphere to flow from Node 2 into the depressurized module through the Node 2 MPEV, described in chapter II, section 3.1.4. This manually-operated valve allows controlled airflow between modules and supports manual atmosphere sampling equipment as well. The MPEV is identical to the MPEV's for the USOS, and is manually actuated from either side of a hatch. The gases necessary to repressurize the JEM, and any other supplies or equipment required to respond to rapid decompression, are provided by the USOS.

3.1.2.6 Respond to Hazardous Atmosphere

The initial response is for the crew to don PBA's, which have a 15 min supply of air or O_2. There are two PBA's in the JEM. When initiated by the crew or ground control the JEM atmosphere can be vented to space to achieve a pressure of less than 2.8 kPa (0.4 psia) within 24 hr. The JEM can be repressurized via the MPEV from space vacuum to a total pressure of 95.8 to 98.6 kPa (13.9 to 14.3 psia) and a ppO_2 of 16.4 to 23.1 kPa (2.38 to 3.35 psia) within 75 hr with O_2 and N_2 from the USOS as specified in SSP 41151, paragraphs 3.2.4.3.5 and 3.2.4.4.5.

3.1.2.6.1 Depressurization Assembly

The JEM uses the same vent and relief valves as the USOS as described in chapter II, section 3.1.

3.1.3 MPLM ACS

The ACS equipment in the MPLM is described below.

3.1.3.1 Control Total Atmospheric Pressure

The total pressure sensor used in the MPLM is the same as the sensor used in the APM, described in section 3.1.1.1.1. The rate of change of pressure (dP/dt) is calculated to determine if there is excessive atmosphere leakage. Control of the atmosphere pressure is provided by the USOS or RS. There is no pressure control panel in the MPLM.

3.1.3.2 Negative Pressure Relief

The negative pressure relief capability provides automatic equalization of the pressure between a module atmosphere and the external environment, such as for returning the MPLM to Earth. Negative pressure relief is also provided to ensure that low pressure weather systems do not lead to buckling of the modules prior to launch. In the MPLM this capability is provided by five assemblies, each including one pneumatic valve and support flange. Four valves are sufficient to maintain the negative differential pressure below 3.45 kPa (0.5 psid), so as to avoid structural collapse. A fifth valve provides single-failure tolerance in case one of the valves fails to open when needed.

3.1.3.3 Control Oxygen Partial Pressure

ppO_2 control capability is provided by the USOS or RS. The major constituent composition of the atmosphere (including O_2) is monitored by the USOS through the SDS that consists of a sample line for delivering atmosphere sam-ples to the USOS, a shutoff valve, and a filter.

3.1.3.3.1 SDS Sample Line

The SDS sample lines in the MPLM are shown in figure 161. The total pressure drop in the MPLM sample line does not exceed 1.03 kPa (0.15 psid) with an airflow rate of 600 sccm at 101.3 kPa (14.7 psia) pressure and 21 °C (70 °F). The sample line is made of AISI 304L stainless steel with an outer diameter (OD) of 3.2 mm (1/8 in). The sample line ends in the MPLM cabin via a threaded duct that allows test and leakage verification by the Gas Servicer. The mechanical interface is a 3.2 mm (1/8 in) threaded fitting.

3.1.3.3.2 SDS Shutoff Valve

A sample line shutoff valve, shown in figure 162, allows isolation of the MPLM from the USOS. The MPLM avionics system controls opening and closing of the sample line shutoff valve. The principal elements of the valve are a main solenoid, a central shaft, a balanced poppet, a latching solenoid, a valve position indicator switch, and a housing. All materials are 304 stainless steel or other corrosion-resistant material. While the poppet is in the open position, air flows through the valve to the outlet port. When the latching solenoid is energized,

the latch is pulled out of the groove on the central shaft, and the poppet spring closes the valve. The valve position indicator senses the position of the central shaft and provides one contact closure for open and another contact closure for closed position indication. The valve interfaces with the sample line ducts through 6.4 mm (1/4 in) fittings.

The characteristics of the sample line shutoff valve include:

- Dimensions
  - 101 by 110 by 127 mm (4 by 4.3 by 5 in)
- Mass
  - 1.4 kg (3.1 lb)
- Pressure drop
  - <0.52 kPa (0.075 psid) at 600 sccm of air at 101.3 kPa (14.7 psia)
- Normal pressure range
  - 95.8 to 104.7 kPa (13.9 to 15.2 psia)
- Temperature range
  - 15 to 40 °C (59 to 104 °F)
- Internal leakage
  - <0.25 sccm of air at 104.7 kPa (15.2 psid)
- Power supply
  - 28 Vdc
- Power consumption
  - 20 W peak during activation (<1 sec).

3.1.3.3.3 SDS Filter

A sample line filter, shown in figure 163, prevents particulates from entering the sample line. The filter consists of a 2 mm absolute filter containing a small HEPA-type cartridge and cleanable 8 by 8 mesh screen. The cartridge life is estimated at 1,451 days, with a 403-day cycle for cleaning the screen. The aluminum housing consists of two threaded pieces to allow access to the filters. Fittings allow attachment to the sampling line.

The characteristics of the sample line filter include:

- Dimensions
  - 33 mm (1.3 in) diameter by 59.4 mm (2.3 in) length
- Mass
  - 0.15 kg (0.33 lb)
- Pressure drop
  - 18 Pa at 600 sccm (0.07 in H_2O) airflow rate.

3.1.3.4 Relieve Overpressure

The atmospheric pressure is maintained to be less than the design maximum internal-to-external differential pressure. Venting of atmosphere to space does not occur at <102.0 kPa (14.8 psid) when the MPLM is isolated. The PPRA in the MPLM is identical to the PPRA in the APM, described in section 3.1.1.3. While attached to the USOS, the USOS performs overpressure relief for the MPLM.

3.1.3.5 Equalize Pressure

The pressure differential between adjacent, isolated modules is equalized by means of the MPEV mounted in the hatch between the modules. The MPLM MPEV is identical with the USOS MPEV, described in chapter II, section 3.1.4.

3.1.3.6 Respond to Rapid Decompression

The differential pressure of depressurization, repressurization, and the depressurized condition can be tolerated by the equipment and structure without resulting in a hazard or failure propagation. The response to rapid decompression is to evacuate the module and seal the Node 2 (or Node 1) hatch to the MPLM, as described in section 6.6. After any necessary repairs are made, the MPLM is repressurized by allowing atmosphere to flow from Node 2 (or Node 1) into the depressurized module through the MPEV, described in chapter II, section 3.1.4. This manually operated valve allows controlled airflow between modules and supports manual atmospheric sampling equipment as well. The MPEV is identical to the MPEV's for the USOS, and is manually actuated from either side of a hatch. The gases necessary to repressurize the MPLM, and any other supplies or equipment required to respond to rapid decompression, are provided by the USOS. The MPLM can also be sealed and returned to Earth for repairs.

3.1.3.7 Respond to Hazardous Atmosphere

The initial response is for the crew to don PBA's, with a 15 min. supply of O_2 or air. When initiated by the crew or ground control the MPLM atmosphere can be vented to space to achieve a pressure of less than 2.8 kPa (0.4 psia) within 24 hr. The MPLM can be repressurized via the MPEV from space vacuum to a total pressure of 95.8 to 98.6 kPa (13.9 to 14.3 psia) and a ppO_2 of 16.4 to 23.1 kPa (2.38 to 3.35 psia) within 75 hr with O_2 and N_2 from the USOS as specified in SSP 41150.

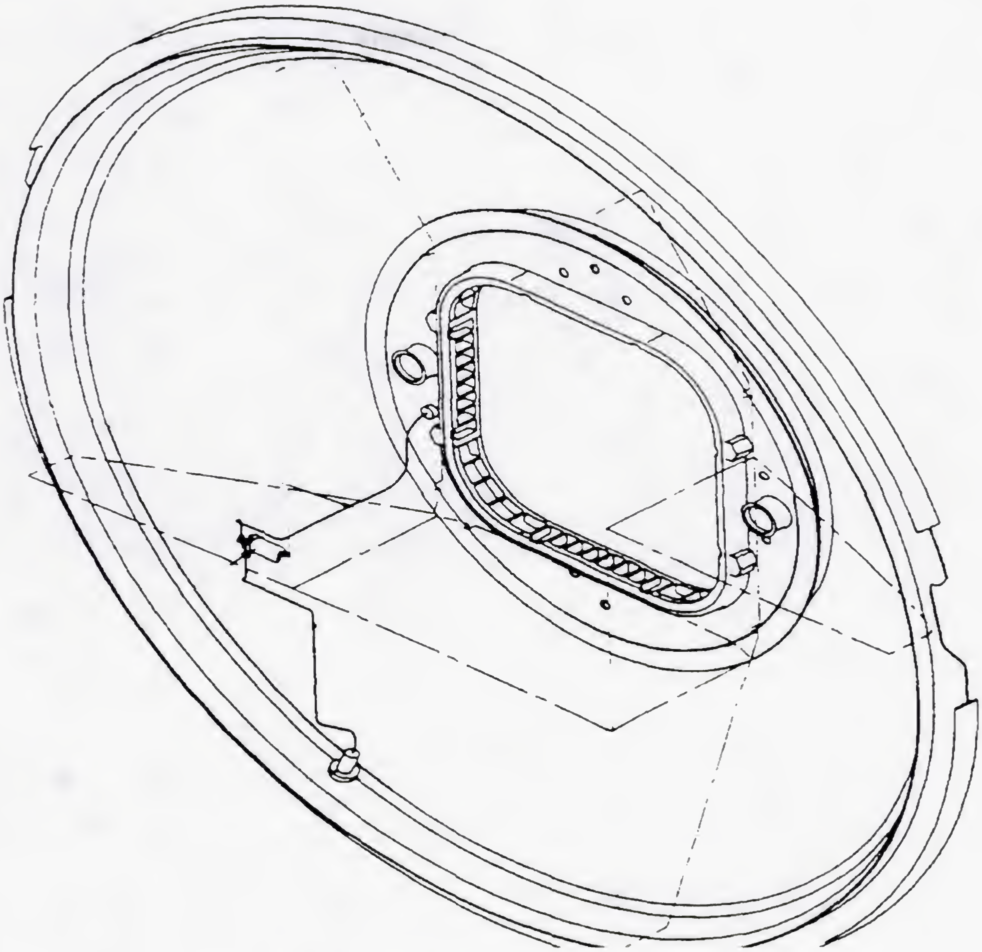


FIGURE 161.—MPLM sample line layout.

3.1.3.7.1 Depressurization Assembly

The MPLM DA is the same as the DA in the APM, described in section 3.1.1.6.1. Depressurization is carried out by 2 DA's both mounted on the forward end cone.

3.2 Temperature and Humidity Control (THC)

The THC subsystems in the APM, JEM, and MPLM are shown schematically in figures 164–166. The function of conditioning the atmosphere within a segment can be separated into several tasks. Some of these tasks are performed in all of the segments (e.g., atmosphere circulation), whereas other tasks are not (e.g., humidity removal). These are described in the following sections for each segment.

3.2.1 APM THC

The APM THC provides control of the atmosphere temperature and humidity, and circulates the atmosphere within the module and ventilates it to the USOS through Node 2. The APM THC subsystem is shown schematically in figure 167. The APM design cabin heat loads are based on 220 W sensible from IMV plus three people working heavily. The maximum cabin heat load on the air loop is 1,300 W sensible and 360 W latent at 18 °C (65 °F), including the maximum heat leak from the ISPR's. The cabin airflow rate into the cabin through the supply diffusers is 408 m^3/hr (240 cfm).

The atmospheric temperature in the cabin is maintained within the range of 18 to 27 °C (65 to 80 °F). The atmosphere temperature setpoint is selectable by the flight or ground crew and the setpoint can be controlled within ±1 °C (±2 °F). The atmosphere RH is monitored by water vapor pressure sensors.

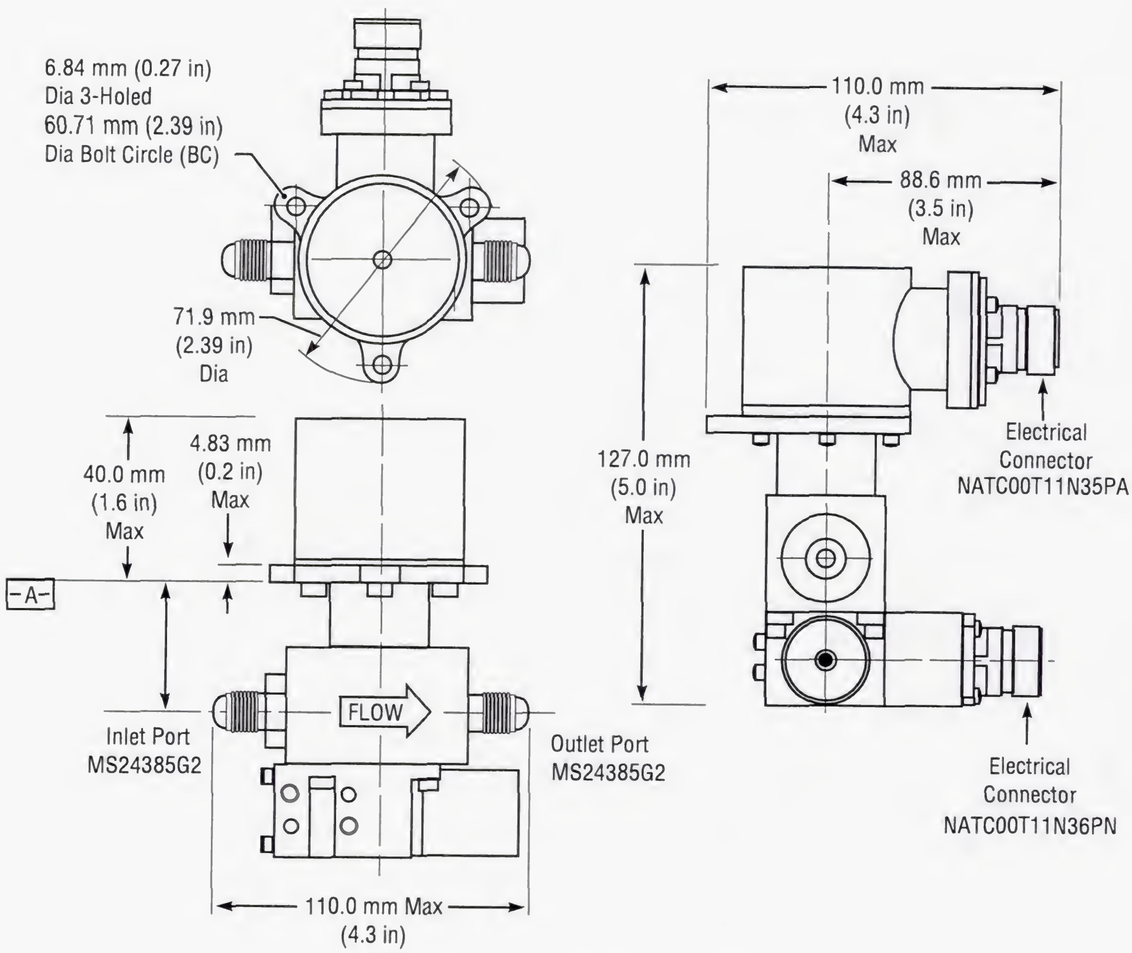


FIGURE 162.—MPLM SDS shutoff valve.

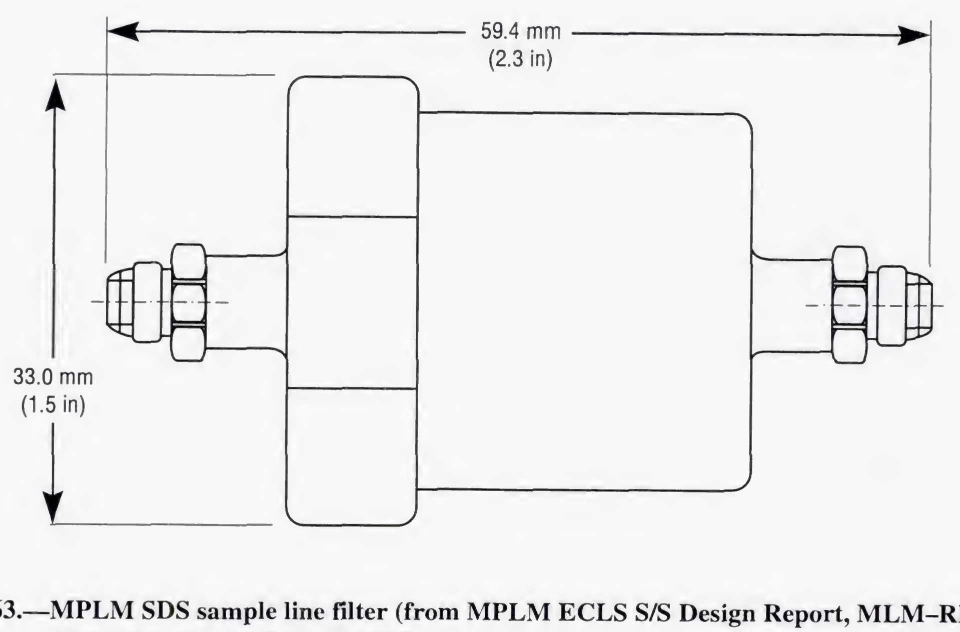


FIGURE 163.—MPLM SDS sample line filter (from MPLM ECLS S/S Design Report, MLM-RP-AI-0084, Alenia Spazio, 8 February 1995).

3.2.1.1 Control Atmosphere Temperature

Controlling the atmosphere temperature requires monitoring the temperature and removing excess heat.

3.2.1.1.1 Monitor Atmosphere Temperature

The APM atmosphere temperature sensor, shown in figure 168, is a platinum resistance probe enclosed in a stainless steel housing, and is mounted in the return IMV line. The main performance and physical characteristics are:

- Dimensions
  - The sensor body is 47.5 mm in length by 19.1 mm diameter (1.87 in length by 0.75 in diameter)
  - The sensor probe is 52.1 mm in length by 3.3 mm diameter (2.05 in length by 0.13 in diameter)
- Mass
  - 50 g (0.11 lb)
- Sensor resistance
  - 1,000 ±1 ohms at 0 °C (32 °F)
- Working temperature range
  - 1.67 to 57.2 °C (35 to 135 °F)
- Accuracy
  - ±0.55 °C (1 °F)
- Input current
  - 1 mA dc.

3.2.1.1.2 Remove Excess Heat

The temperature is maintained between 18.3 and 27 °C (65 an 81°F). Excess heat is removed by a CHX unit that is designed, as shown in figure 169, so that the CHX's can be dried out. To enable this feature, atmosphere is drawn into the CHX unit by two cabin fans that are in parallel, with one being a backup to the other. The atmosphere then flows through a common HEPA filter before being split, with some atmosphere going through the heat exchanger being dried and the rest going through the active CHX. The atmosphere streams recombine at the temperature control valve. The CHX inlet coolant temperature is 4 to 6 °C (39 to 43 °F) and the coolant flowrate is 250 to 600 kg/hr (113 to 272 lb/hr).

Active avionics air cooling is provided to payload and experiment racks that require cooling. The AAA is identical with the USOS AAA, described in chapter II, section 3.2.1.3.

3.2.1.2 Control Atmosphere Moisture

The RH is maintained from 25 to 70 percent RH. Humidity in the APM is actively controlled by the CHX unit. Each CHX has its own water separator and water condensed from the atmosphere is delivered to the USOS via a dedicated line in accordance with SSP 41150. The return air line from the condensate water separator is connected to the main loop downstream of the CHX.

3.2.1.3 Circulate Atmosphere Intramodule

Eight supply air diffusers are located in the upper standoffs of the APM. The diffuser, shown in figure 170, allows the ventilation flow to be directed where it is needed. The exact design had not yet been selected as of this writing, but probably will be similar to the design shown.

These diffusers ensure that:

- The air velocity is between 0.076 and 0.203 m/sec (15 and 40 fpm) in the cabin, excluding zones adjacent to cabin walls (within 15.2 cm (6 in) of the rack fronts).
- The average air velocity requirement is achieved at least within the 67 percent of the habitable area measurement points.
- The air velocity averaged over time is always in the range of 0.036 to 1.016 m/sec (7 to 200 fpm).

Ventilation is also provided in the standoffs, end-cones, and deck floor mainly for smoke collection and transport. There is no flow control during steady-state operation.

3.2.1.4 Circulate Atmosphere Intermodule

Ventilation of the APM cabin provides revitalized atmosphere from the USOS. IMV is performed by two IMV fans in the APM, as shown in figure 167, to ensure sufficient flow.

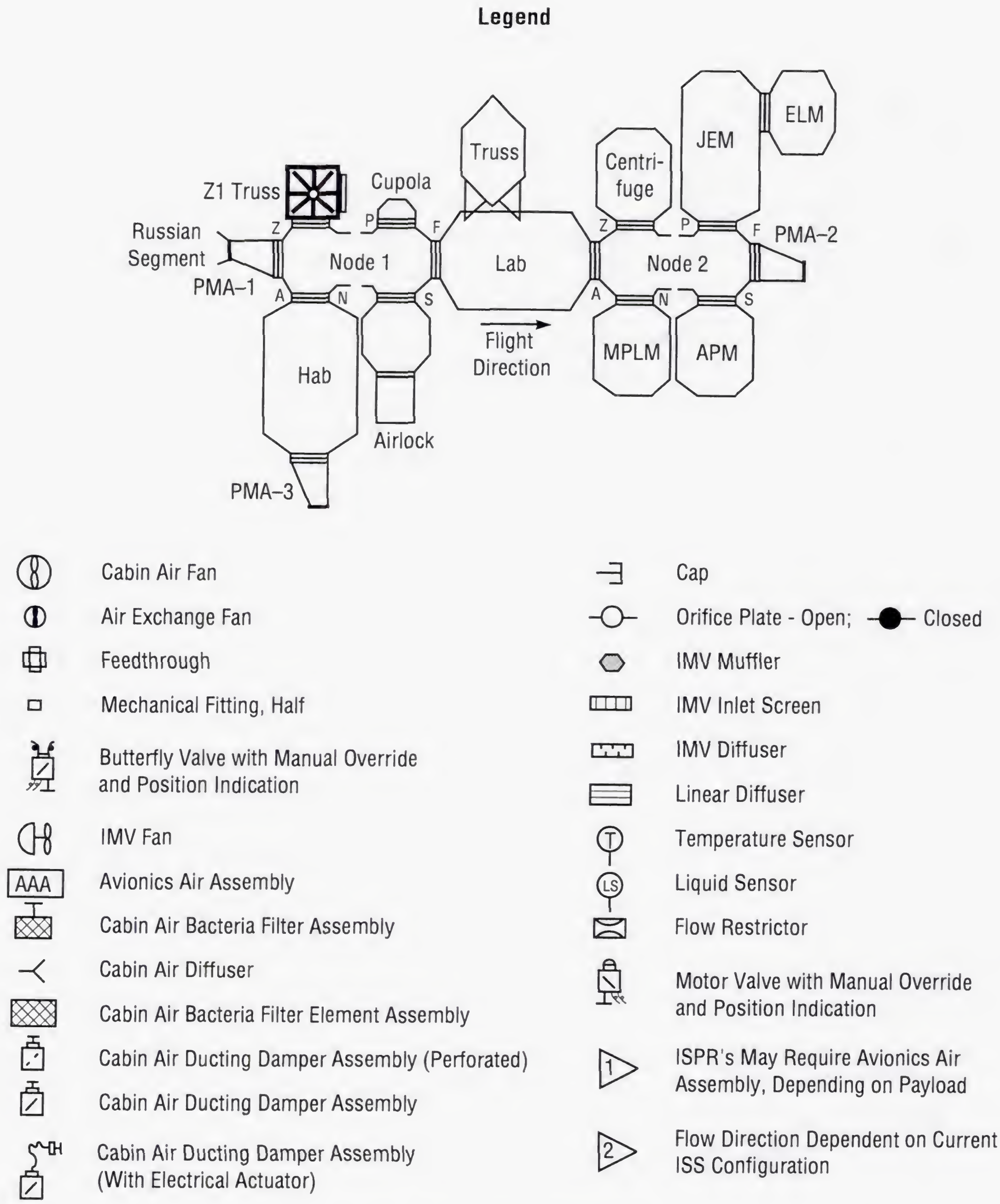
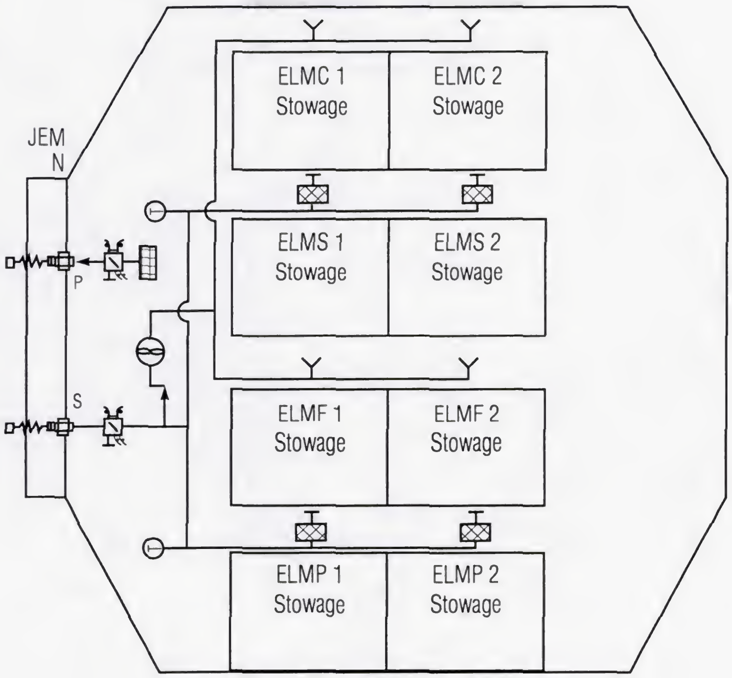


Figure 164.—THC subsystems.

The IMV supply and return lines are cross coupled to provide a by-pass of the cabin, if desired. There are four common fan assemblies (all located in the port endcone) that provide for IMV, atmosphere circulation, and THC. There is a single CHX assembly, with two cores in parallel to allow for drying out the cores without losing the function. The Temperature Control Valve (TCV) is controlled by Cabin Temperature Controller Units (CTCU). The THC control law is embedded in the CTCU, commanding the TCV on the basis of atmosphere temperature sensor readings and the relevant set-point. The cabin atmosphere temperature, RH, and water carryover are monitored.

JEM–ELM



JEM-PM

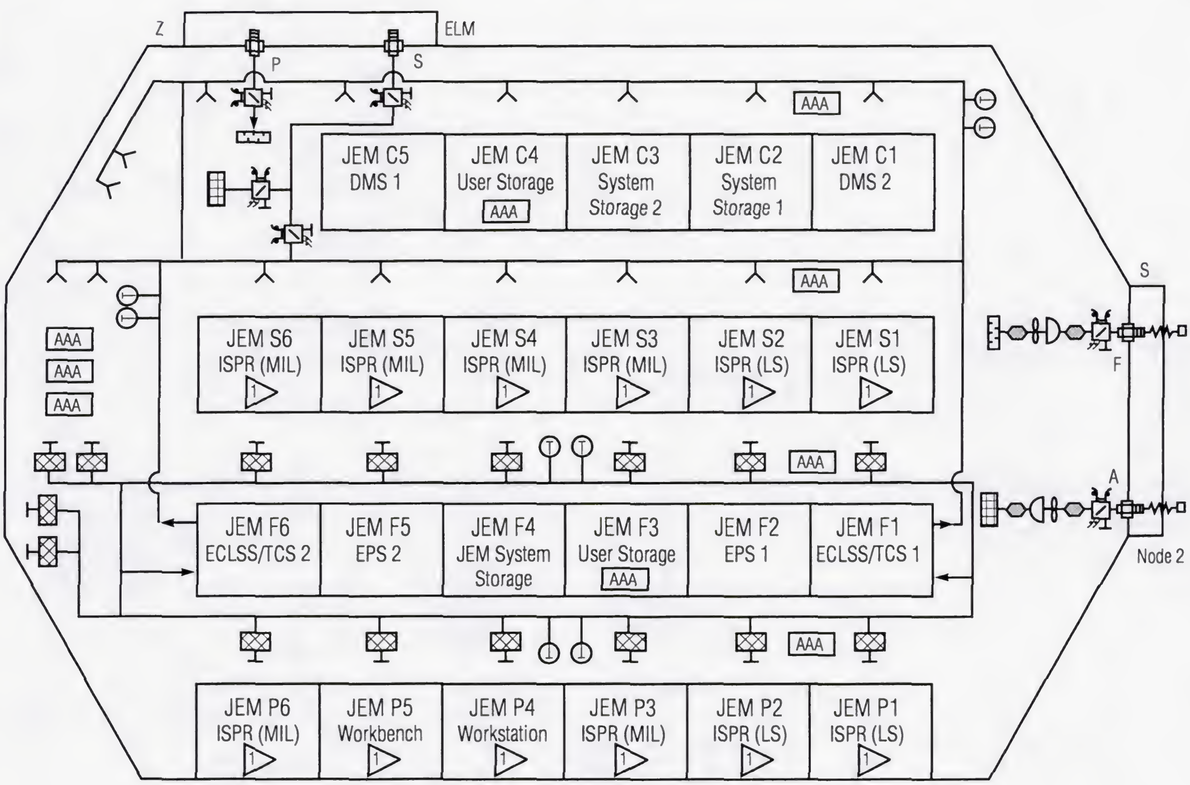
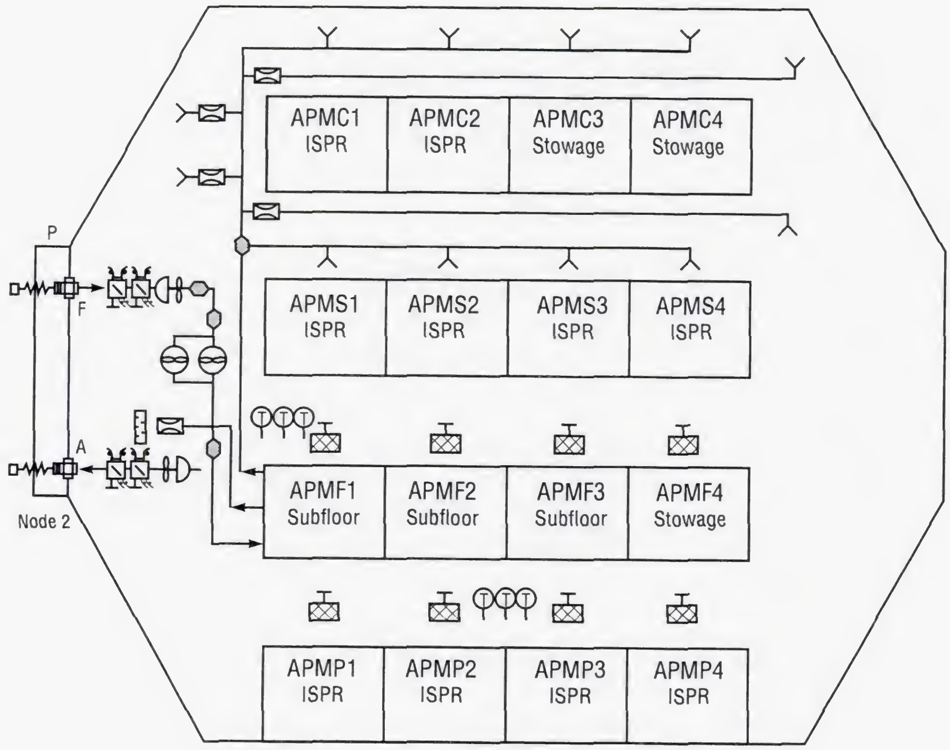


FIGURE 165.—THC subsystems (continued).

APM



MPLM

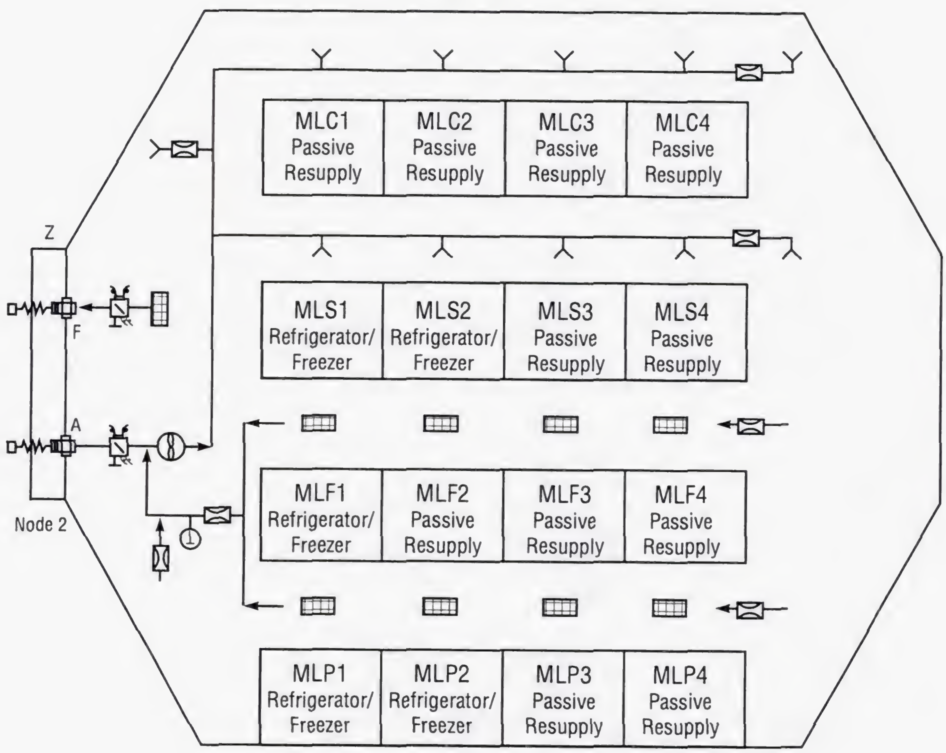


FIGURE 166.—THC subsystems (continued).

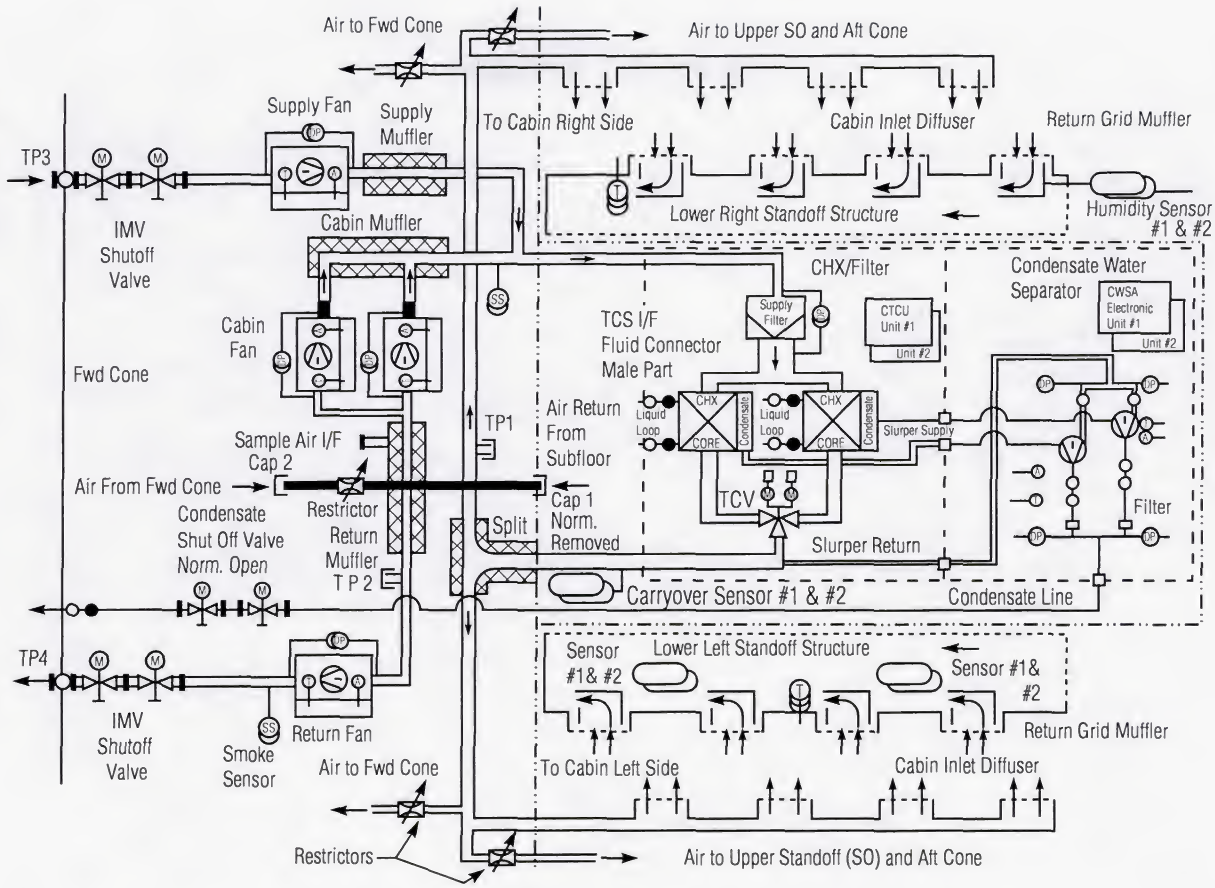


Figure 167.—APM THC subsystem functional schematic (from ECLSS TIM, APM ECLSS presentation, Houston, TX, 24 to 28 July 1995).

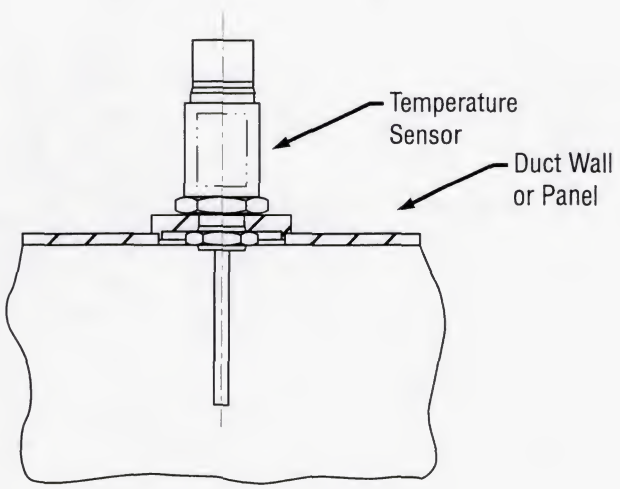


Figure 168.—APM air temperature sensor.

3.2.2 JEM THC

The JEM THC provides control of the atmosphere temperature and humidity, circulates the atmosphere within the module, and ventilates it to the USOS through Node 2. The JEM THC subsystem is shown schematically in figure 171, and the CHX and water separator are shown in figure 172.

The THC subsystem performs the following functions:

- *Control temperature and humidity in PM and ELM*
- Support crew-selectable cabin temperature under nominal conditions
- Maintain air circulation within the PM
- Support airflow adjustment
- Remove airborne particulates and microbes.

The THC subsystem in the PM consists of the following components:

- Cabin Atmosphere Conditioning and Circulation
  - Cabin Atmosphere Units (CCAA's) (two)
  - Inlet (two) and Outlet (two) Temperature Sensors
  - Supply/Return Ducting and Diffusers
- IMV
  - Motor/Manual IMV Valves (four)
  - Manual Damper Valves to provide conditioned air to the ELM (two)
  - IMV Ducting and Diffusers
- Avionics Air Cooling and Fire Detection Support
  - AAA (two) for the subsystem racks.

The THC subsystem in the ELM–PS consists of the following components:

- Cabin Air and IMV Circulation
  - Cabin/IMV Circulation Fan
  - Inlet (two) Temperature Sensors
  - Motor/Manual IMV Valves (two)
  - Cabin Air and IMV Supply/Return Ducting and Diffusers.

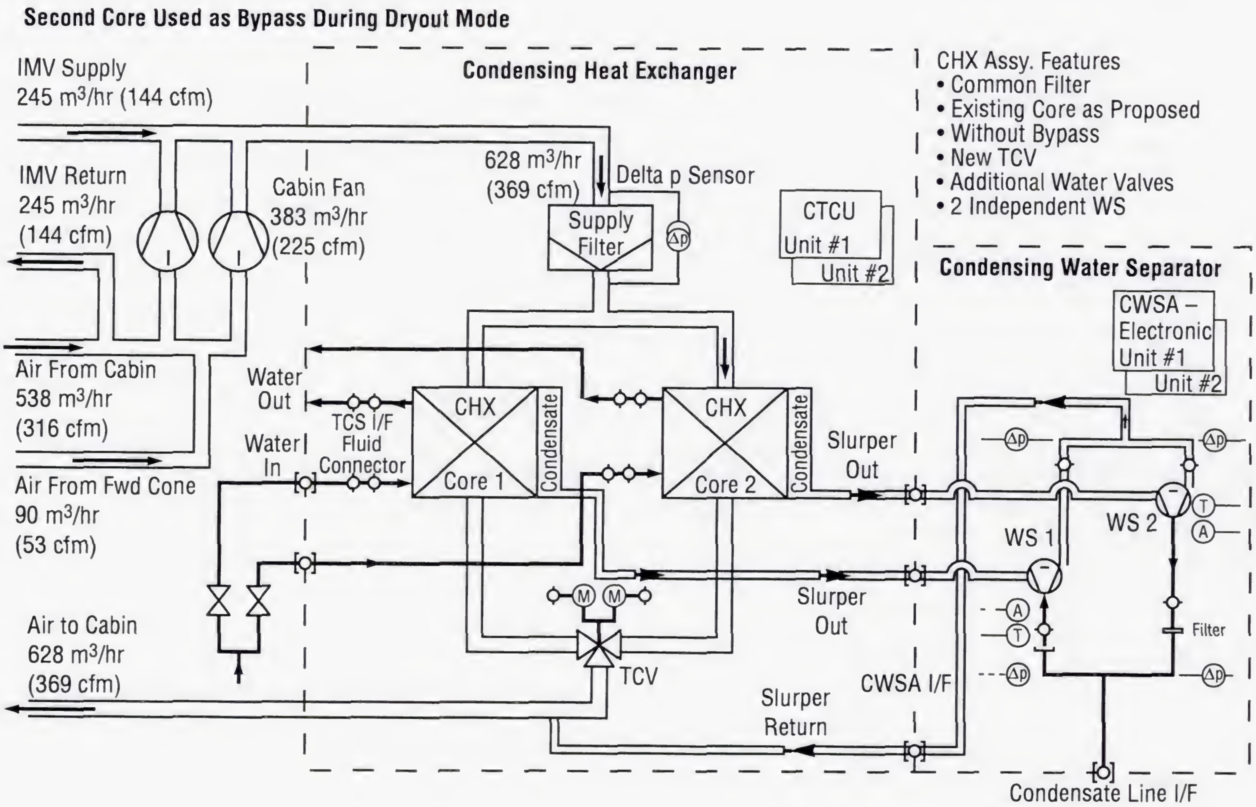


FIGURE 169.—APM THC CHX Schematic (from ECLSS TIM, APM ECLSS presentation, Houston, TX, 24 to 28 July 1995).

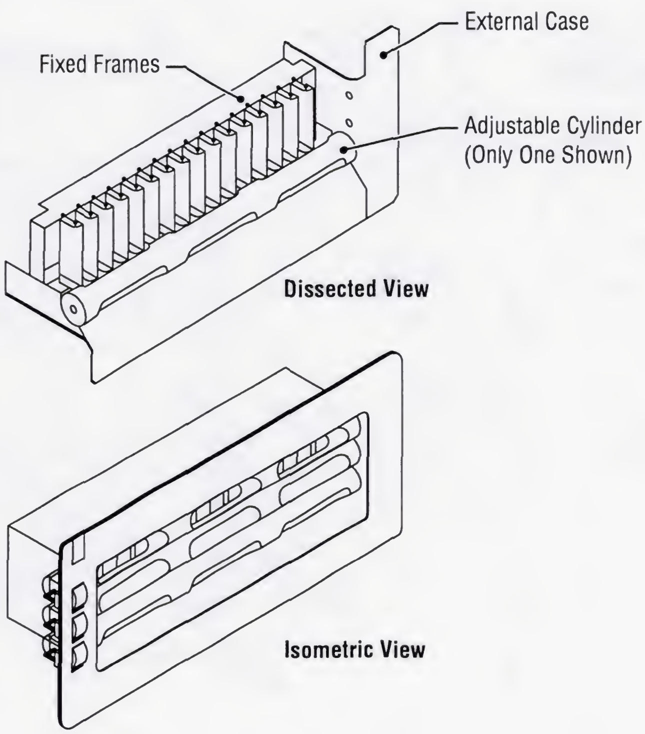


FIGURE 170.—APM air diffuser.

The THC subsystem consists of the following components:

- Bacteria/Particulate (HEPA) Filter
  - Maintains 100k clean room environment (per requirements)
  - Removes airborne microbes and particulates
  - Housing allows easy filter removal/ replacement
  - Two ΔP sensors monitor filter usage
  - Located at cabin air unit inlet.
- Temperature Control Valve
  - Provides cabin air temperature control by regulating airflow distribution through the CHX and bypass
  - Motor-driven drum type three-way valve with position indicator
    - Actuator drive torque is 30 kg-cm (26.4 in-lb) (minimum)
  - Valve position is set according to commands received from the controller
    - Bypass setting range: 0.1 to 0.8.

The entire subsystem is controlled by an 8-bit computer processing unit (CPU), cooled by a coldplate on the MTL coolant loop, that provides the following functions:

- Communications
- Equipment control
- Status monitor
- BIT
- Power supply (except fan)
- Driver for H_2O separator.

3.2.2.1 Control Atmosphere Temperature

The atmosphere temperature in the cabin aisleway (in the ELM) is maintained within the range of 18.3 to 29.4 °C (65 to 85 °F) and 18.3 to 26.7 °C (65 to 80 °F) in the laboratory aisleway (in the PM). The atmosphere temperature setpoint is selectable by the flight or ground crew and the setpoint can be controlled within ±1 °C (±2 °F) during normal operation at 18.3 to 26.7 °C (65 to 80 °F) for nominal loads or 21.1 to 26.7 °C (70 to 80 °F) for high heat loads. Temperature selectability is not required during peak heat load conditions.

3.2.2.1.1 Monitor Atmosphere Temperature

The JEM atmosphere temperature is monitored by sensors that are similar to those used in the USOS (platinum resistance), but are specially made for the JEM. The sensor characteristics are listed in table 43.

To provide closed-loop control and support for the CCAA's there are:

- Six temperature sensors located in cabin ducts
  - Two sensors located in PM cabin air return ducts (closed-loop control)
  - Two sensors located in PM cabin air supply ducts (FDIR)
  - Two sensors located in ELM cabin air return ducts (FDIR)
- Six temperature sensors located in each CCAA
  - Two inlet sensors (FDIR)
  - Two outlet sensors (FDIR)
  - LTL inlet and outlet sensors (FDIR).

TABLE 43.—*JEM temperature sensor characteristics.*

Sensor Characteristics	Metric Units	U.S. Units
Range	0 to 50°C	0 to 122 °F
Accuracy	± 0.5°C	± 1 °F
Operating Environment		
Temperature	0 to 50 °C	0 to 122 °F
Pressure	1.9×10^{-7} to 14.9 psia	1.3×10^{-6} to 102.7 kPa
Power	28 Vdc	28 Vdc
Data	0 to 5 Vdc (Analog)	0 to 5 Vdc (Analog)

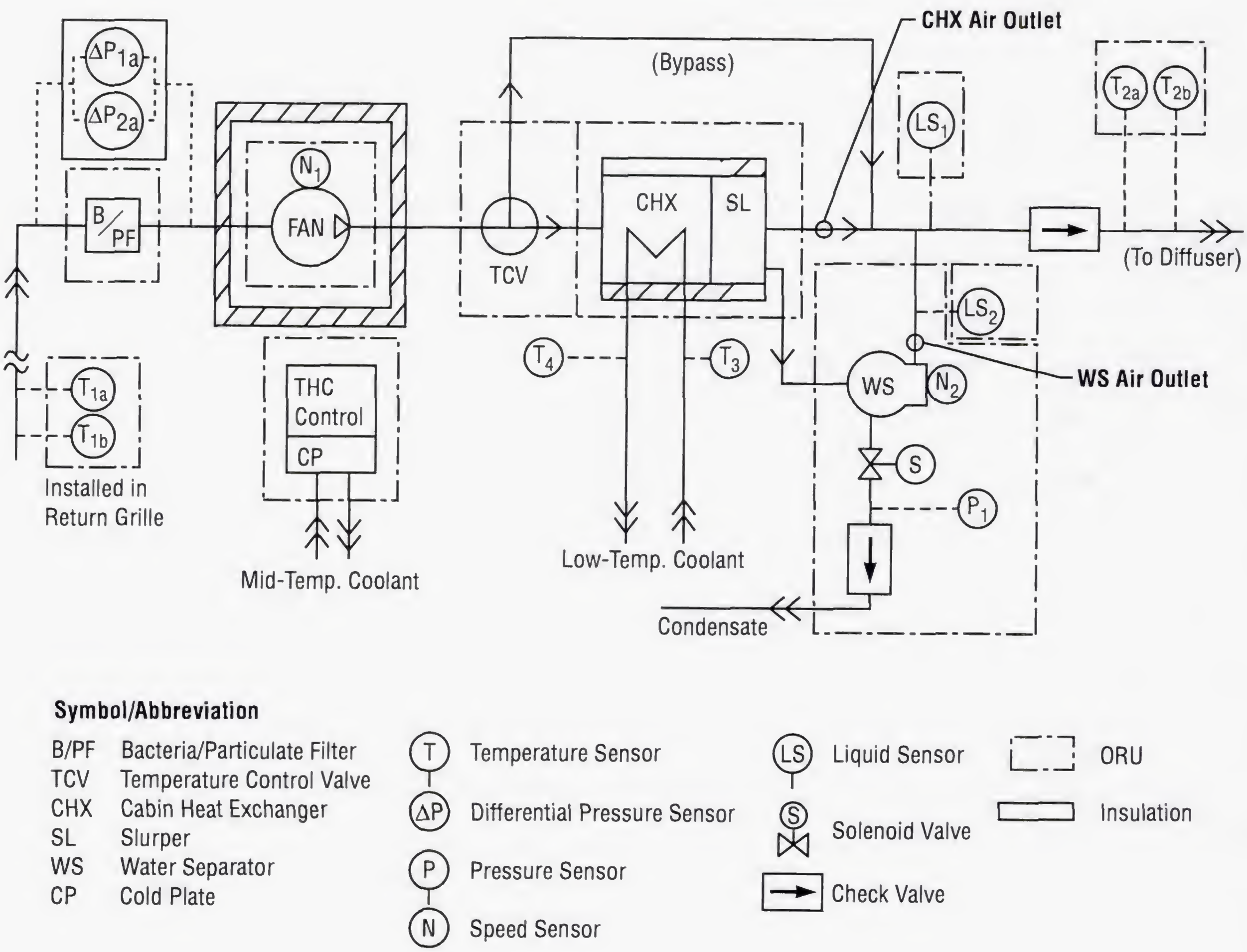


FIGURE 171.—JEM THC subsystem.

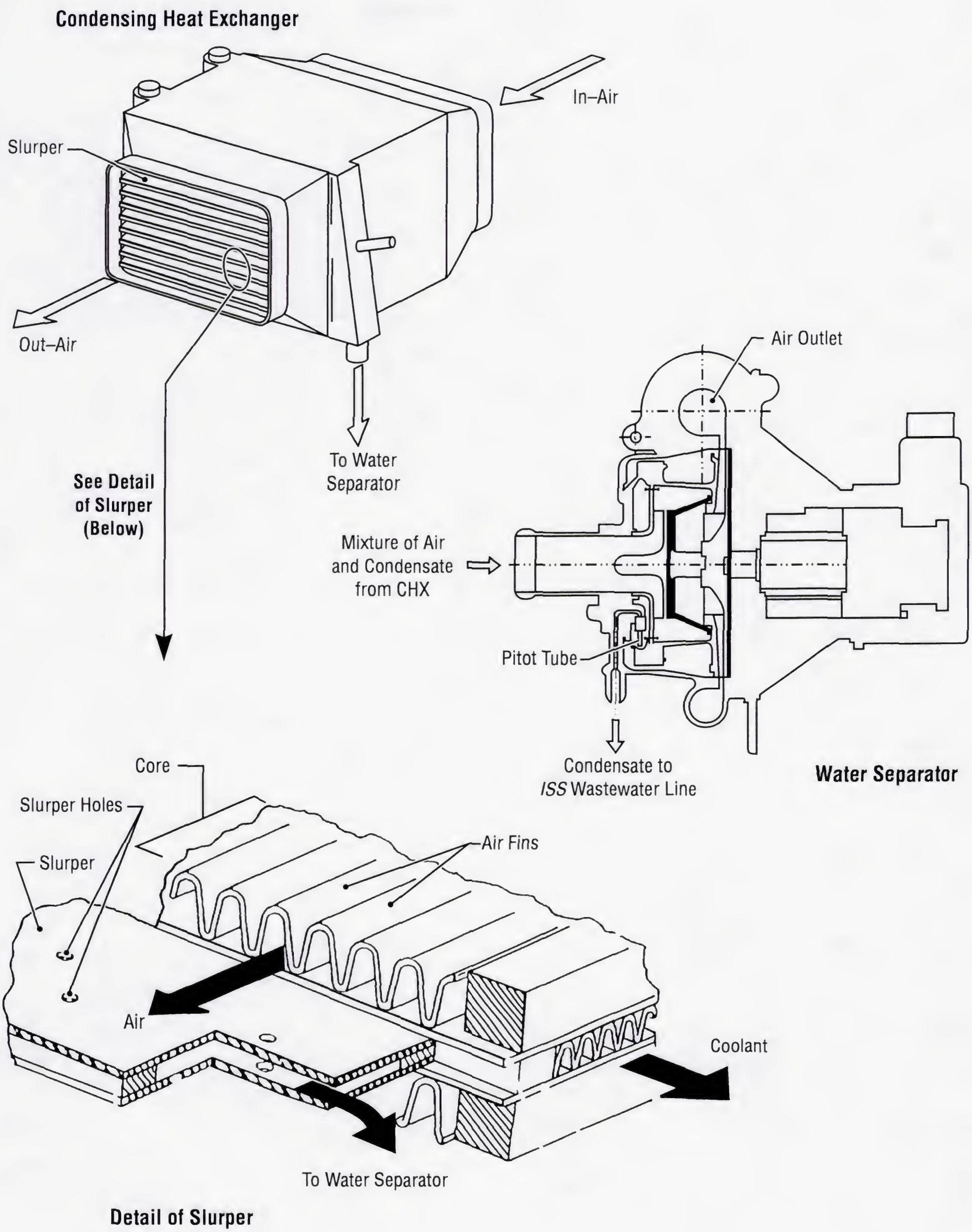


FIGURE 172.—JEM CHX and water separator.

3.2.2.1.2 Remove Excess Heat

Excess atmospheric heat is removed by a CHX unit, shown in figure 172, that uses a fan and liquid sensors that are identical with the CCAA in the USOS, described in chapter II, section 3.2.1.2.

Excess equipment heat is removed by the AAA, identical with the USOS AAA, described in chapter II, section 3.2.1.3. The CCAA can remove 2.2 kW of sensible heat and 0.1 kW of latent heat.

The MTL interfaces with two Cabin Air Unit Controller Coldplates, the AAA for RMS console, and a Vacuum Pump.

Avionics air cooling provides the following functions for the two subsystem racks:

- Heat removal from powered equipment.
- Ventilation in support of smoke detection and atmosphere monitoring.

3.2.2.2 Control Atmosphere Moisture

The atmospheric RH in the cabin aisleway is maintained within the range of 25 to 70 percent, and the dewpoint within the range of 4.4 to 15.6 °C (40 to 60 °F). The LTL interfaces with two Cabin Air Unit Condensing Heat Exchangers, as shown in figure 172, to provide humidity control in the JEM. Water condensed from the atmosphere in the CHX is collected by a water separator and delivered, via a wastewater line, to the USOS in accordance with SSP 41151, paragraph 3.2.4.2.4.

A CHX and "slurper" provide cabin air cooling, humidity condensation, and condensate collection. The CHX is a plate fin HX with a hydrophilic film to aid condensation. There are redundant liquid sensors downstream for FDIR.

The water separator is a centrifugal type separator with a brushless dc motor and a speed sensor. It separates condensate and air and delivers condensate to the condensate bus at 0 to 55 kPa (0 to 8 psig) gauge pressure (101 to 156 kPa, 14.7 to 22.7 psia absolute pressure). One liquid sensor is located in the air return line to detect any water carryover. The condensate return line consists of a solenoid valve, pressure sensor, and check valve (similar to USOS cabin air unit). A filter is located at the separator inlet. The condensate processing capacity is 0.2 kg/hr (0.44 lb/hr) (minimum).

3.2.2.3 Circulate Atmosphere Intramodule

The effective atmosphere velocities in the cabin aisleway are maintained within the range of 0.08 to 0.2 m/sec (15 to 40 fpm), as shown in figure 173. The Cabin Air Recirculation Fan provides air circulation through the CHX and the cabin. The fan has a brushless dc motor and speed sensor and two ΔP sensors. The conditions at three operating points are listed in table 44.

3.2.2.4 Circulate Atmosphere Intermodule

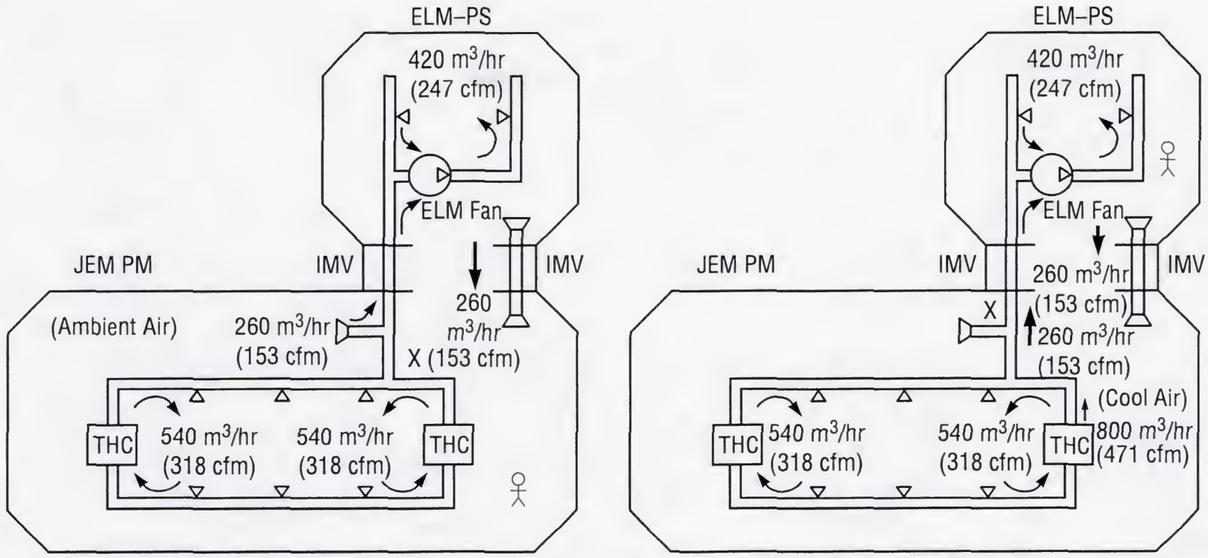
Atmosphere is exchanged with the USOS as specified in SSP 41151, paragraph 3.2.4.1. (at a rate of 63.7 to 68.4 L/sec (135 to 145 ft^3/min).) The conditions of the atmosphere supplied to the JEM are listed in table 45.

IMV performs the following functions:

- Provides air exchange between the PM, ELM–PS, and USOS.
- Supports CO_2 and trace gas removal from PM and ELM-PS.
- Supports ppO_2 control throughout the *ISS*.
- Supports cabin air circulation.

TABLE 44.—JEM intramodule circulation conditions.

Fan Performance	Operating Point A	Operating Point B	Operating Point C
Airflow Rate Pressure Rise	800 m^3/hr (471 cfm) 164 mm H_2O (6.45 in H_2O)	600 m^3/hr (353 cfm) 108 mm H_2O (4.25 in H_2O)	400 m^3/hr (235 cfm) 65 mm H_2O (2.56 in H_2O)



1. PM/ELM IMV (ELM Unoccupied) **2. PM/ELM IMV (ELM Occupied)**

FIGURE 173.—JEM intramodule circulation.

TABLE 45.—*IMV supply to the JEM interface conditions.*

Parameter	Units	Range
Dewpoint (1)	°C (°F)	4.3 to 15.6 (40 to 60)
Total Pressure (1) (3)	hPa (psia)	978 to 1,027 (14.2 to 14.9)
ppO_2 (1)	hPa (psia)	195 to 231 (2.83 to 3.35)
$ppCO_2$ (1) (nominal)	mmHg	<5.3 daily average, <7.6 peak
$ppCO_2$ (1) (crew exchange)	mmHg	<7.6 daily average, <10.0 peak
RH	Percent	25 to 70
Trace Contaminants (2)	ppm	Cabin Atmosphere
Particulates (Daily Average) (0.5 to 100 μm)	PC/m^3 (PC/ft^3)	<3.53x10^6 (<1×10^5)

Notes:
(1) Atmosphere composition in the JEM is controlled by the USOS according to SSP 41000, section 3.
(2) Trace contaminants are controlled in the JEM by the USOS according to NHB 8060.1B.
(3) The transient pressure range is 95.8 to 104.7 kPa (13.9 to 15.2 psia).

The IMV system consists of valves, fans, and other components listed below:

- IMV valves (four)
  - Supports remote IMV activation/isolation for JEM ingress/egress and ELM–PS ingress/egress
  - Identical to USOS IMV valves
  - Motor-driven valves with manual override (O/R), on/off position indicators, and position switch
  - Two located on PM starboard (stbd) endcone and two located on ELM–PS zenith (zen) endcone
- IMV fans (two)
  - Provide supply and return IMV flow between JEM and USOS
    - One fan is used during open hatch operations (preferably the return fan to support atmosphere sampling)
  - Identical to USOS IMV fans
  - Both located on PM stbd endcone
  - Provide 63.7 to 68.4 L/sec (135 to 145 cfm) flowrate during operations with or without a crew

- Manual IMV valves (four)
  - Manual valves with on/off position (two)
    - Control ELM–PS IMV supply air from PM cabin air duct or cabin area
  - Manual valve with on/off position and position switch (two)
  - Valves located on PM-side of hatch
- ELM–PS circulation fan
  - Provides cabin air circulation within ELM–PS
  - Mixes PM IMV air with ELM–PS cabin air
  - Same design as the Node 1 fan.

3.2.3 MPLM THC

The THC functions in the MPLM are performed mostly in the USOS. Circulation of the atmosphere is performed in the MPLM, as described below.

3.2.3.1 Control Atmospheric Temperature

This capability is provided by the USOS.

3.2.3.2 Control Atmospheric Moisture

This capability is provided by the USOS.

3.2.3.3 Circulate Atmosphere Intramodule

The effective atmosphere velocities in the cabin aisleway are maintained within the range of 0.08 to 0.2 m/sec (15 to 40 fpm) by the MPLM cabin fan located on the forward end cone. The circulation pattern is shown in figure 174. When the MPLM is in the space shuttle cargo bay internal atmosphere circulation is maintained to provide fire detection capabilty.

The major components of the intramodule atmosphere circulation system are:

- The IMV supply duct from the USOS (124 mm (4.9 in) external diameter)
- The IMV return duct to the USOS (124 mm (4.9 in) external diameter)
- IMV shutoff valves
- 8 Cabin air diffusers (identical with the APM diffusers described in section 3.2.1.3.)
- Acoustic noise attenuators (flow straightener, etc.)
- Fan assembly (same as USOS Node 1 ventilation fan)
- Atmosphere temperature sensor.

3.2.3.4 Circulate Atmosphere Intermodule

Atmosphere is exchanged with the USOS, as specified in SSP 42007, at a rate of 63.7 to 68.4 L/sec (135 to 145 ft^3/min).

MPLM cabin ventilation provides revitalized atmosphere from the USOS. IMV is performed by the CCAA in Node 2 when the MPLM is attached to Node 2 and by the U.S. Lab CCAA when the MPLM is attached to Node 1. The MPLM depends on the IMV fan in the node to provide the pressure needed, since there is no additional fan in the MPLM.

3.3 Atmosphere Revitalization (AR)

The AR subsystems in the APM, JEM, and MPLM are shown schematically in figures 175–177, and are described in the following sections for each segment. These AR subsystems rely on the USOS or RS to perform most of the AR functions. One AR function that is common to the APM, JEM, and MPLM is the SDS for collecting atmosphere samples and delivering them to the USOS for analysis for atmosphere constituents. This is described further in chapter II, section 3.3.2.1.4. The ability to respond to hazardous atmosphere conditions is also present in each module. For emergency situations, PBA's (described in chapter II, section 3.3.3) are available that provide 15 min of oxygen from bottled gas (there are no O_2 ports in the APM, JEM, or MPLM).

3.3.1 APM AR

The APM AR subsystem provides atmosphere samples to the USOS for analysis and removes airborne particulates and microorganisms by HEPA filters (that are part of the THC subsystem) as described in the following sections.

3.3.1.1 Control CO_2

This capability is provided by the USOS or RS via IMV. The $ppCO_2$ is, however, monitored in the APM using an electrochemical sensor.

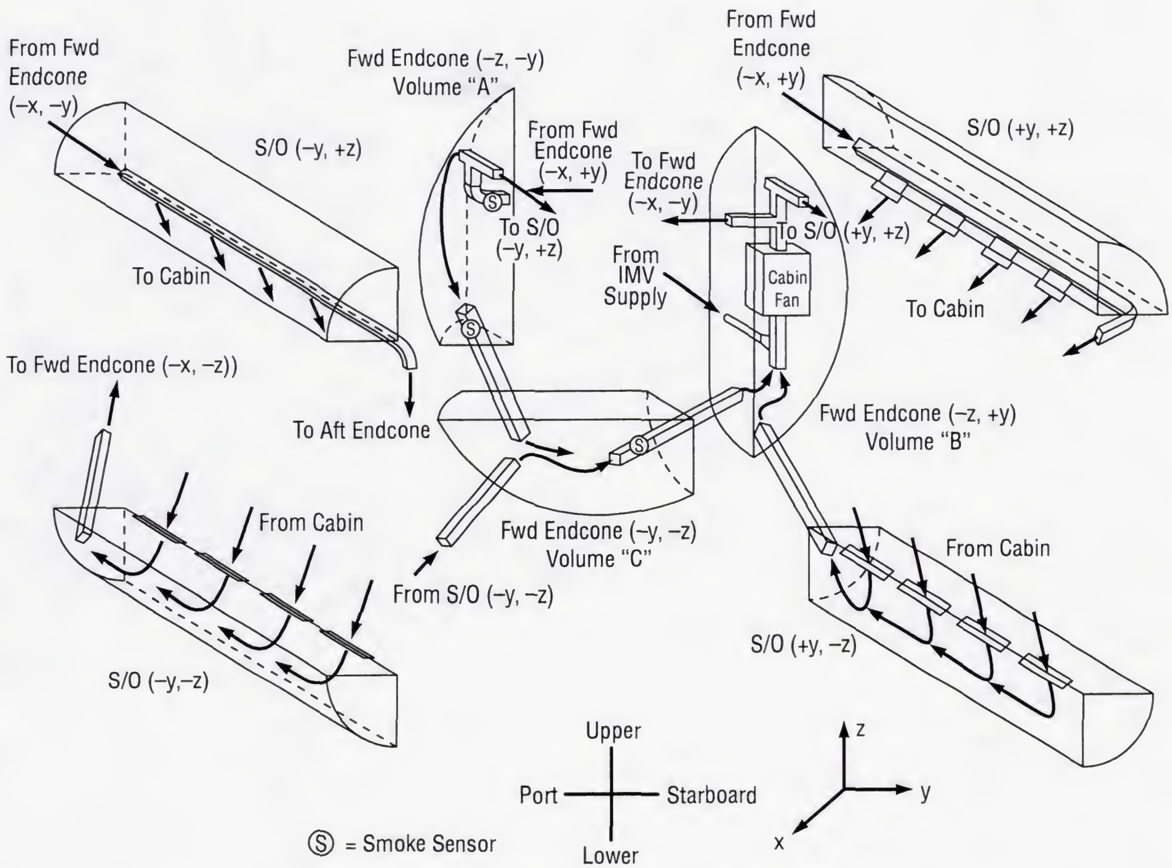


FIGURE 174.—Atmosphere circulation in the MPLM.

3.3.1.2 Control Gaseous Contaminants

Primary control is provided by the USOS or RS via IMV. The capability to initiate depressurization of the APM to remove a hazardous atmosphere is provided, via the DA described in section 3.1.1.6.1.

3.3.1.2.1 Monitor Gaseous Contaminants

Trace contaminant monitoring is performed by the CHeCS, which is part of the USOS "crew systems" rather than ECLS.

3.3.1.3 Control Airborne Particulate Contaminants

Particulates and microorganisms are removed from the atmosphere by HEPA filters in the ventilation supply and return ducts. While the revitalized atmosphere provided to the APM from the USOS meets the contamination requirements, HEPA filters are provided in the supply ducts for additional assurance. HEPA filters are provided in the return ducts to ensure that any contamination generated in the APM does not contaminate the USOS. These HEPA filters are similar to those in the USOS, described in chapter II, section 3.2.3, but are a different size. Atmosphere filtration is centralized by locating a single HEPA filter upstream of the CHX.

The average atmosphere particulate level complies with class 100,000 clean room requirements.

3.3.1.4 Control Airborne Microbial Growth

Airborne microorganisms are also controlled by the HEPA filters that control airborne particulate contaminants. The daily average concentration of airborne microorganisms is limited to <1,000 CFU/m^3 (28 CFU/ft^3).

3.3.2 JEM AR

The JEM AR subsystem provides atmosphere samples to the USOS for analysis and removes airborne

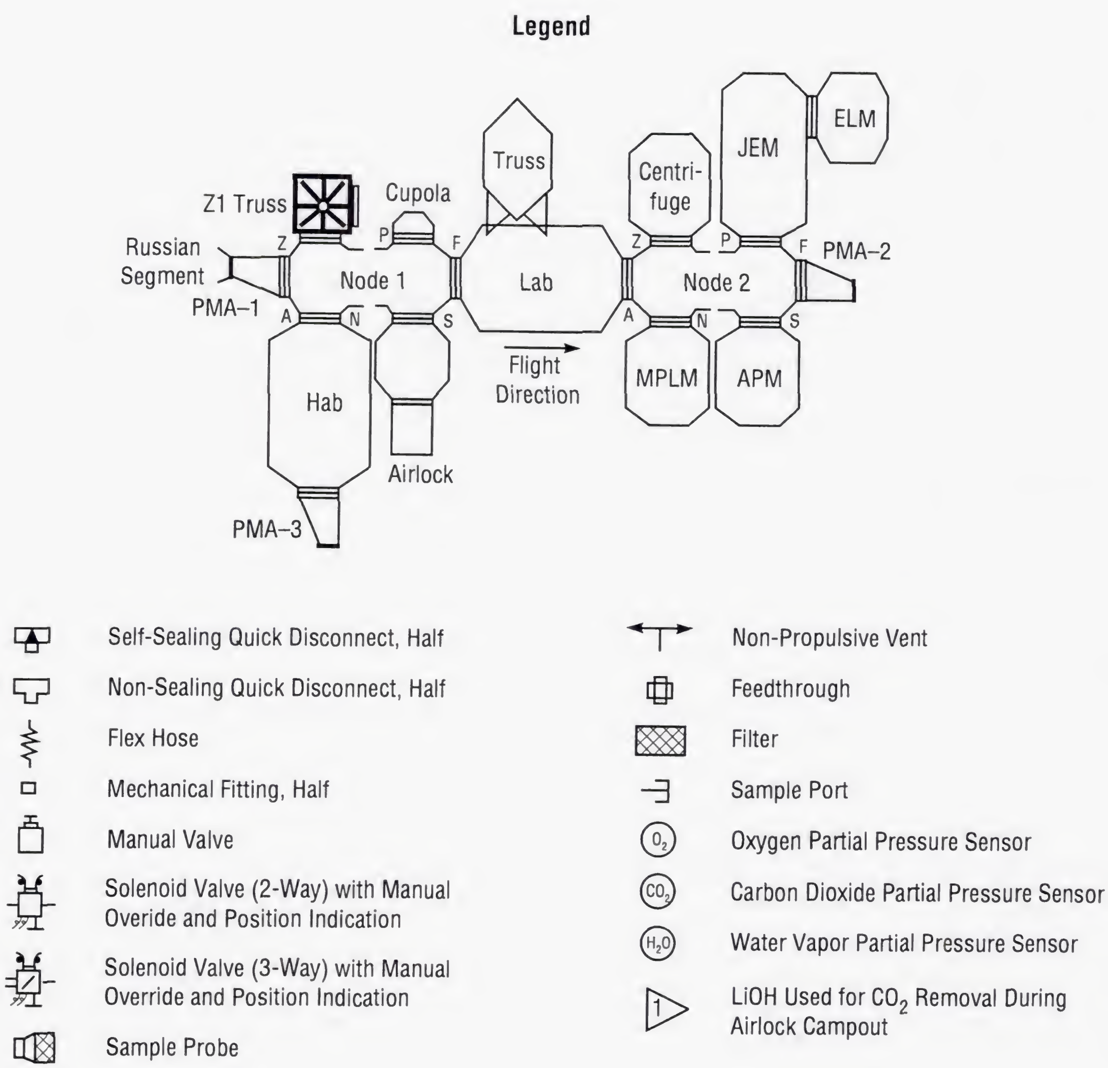


FIGURE 175.—AR subsystem schematic.

particulates and microorganisms by HEPA filters (that are part of the THC subsystem) as described in the following sections. The AR components are distributed in the PM and ELM–PS as follows:

- PM AR components:
  - Solenoid/manual valve (two)
  - Manual valve (one)
  - Sample lines
  - Sample probe/filter.
- ELM–PS AR components:
  - Solenoid/manual valve
  - Sample lines
  - Sample probe/filter.

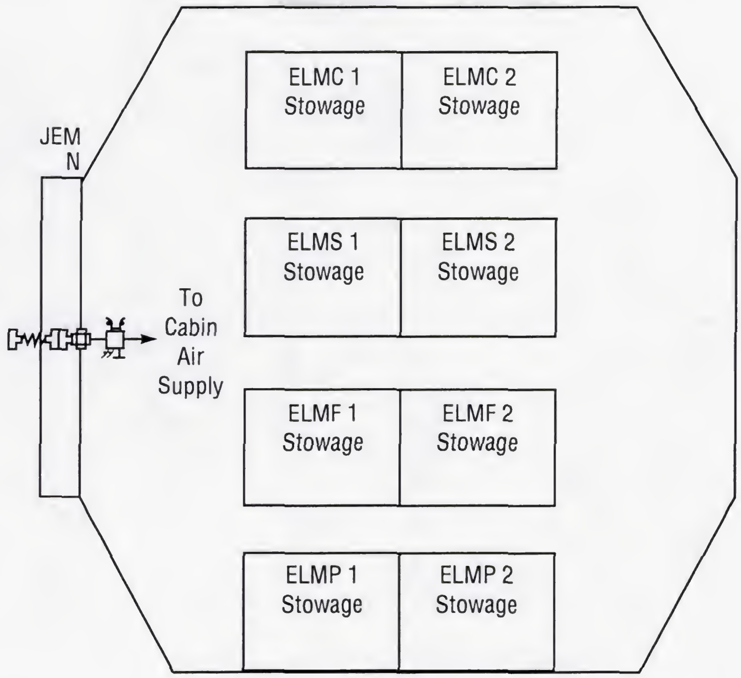
3.3.2.1 Control CO_2

This capability is provided by the USOS or RS via IMV.

3.3.2.2 Control Gaseous Contaminants

Primary control is provided by the USOS or RS via IMV.

JEM–ELM



JEM–PM

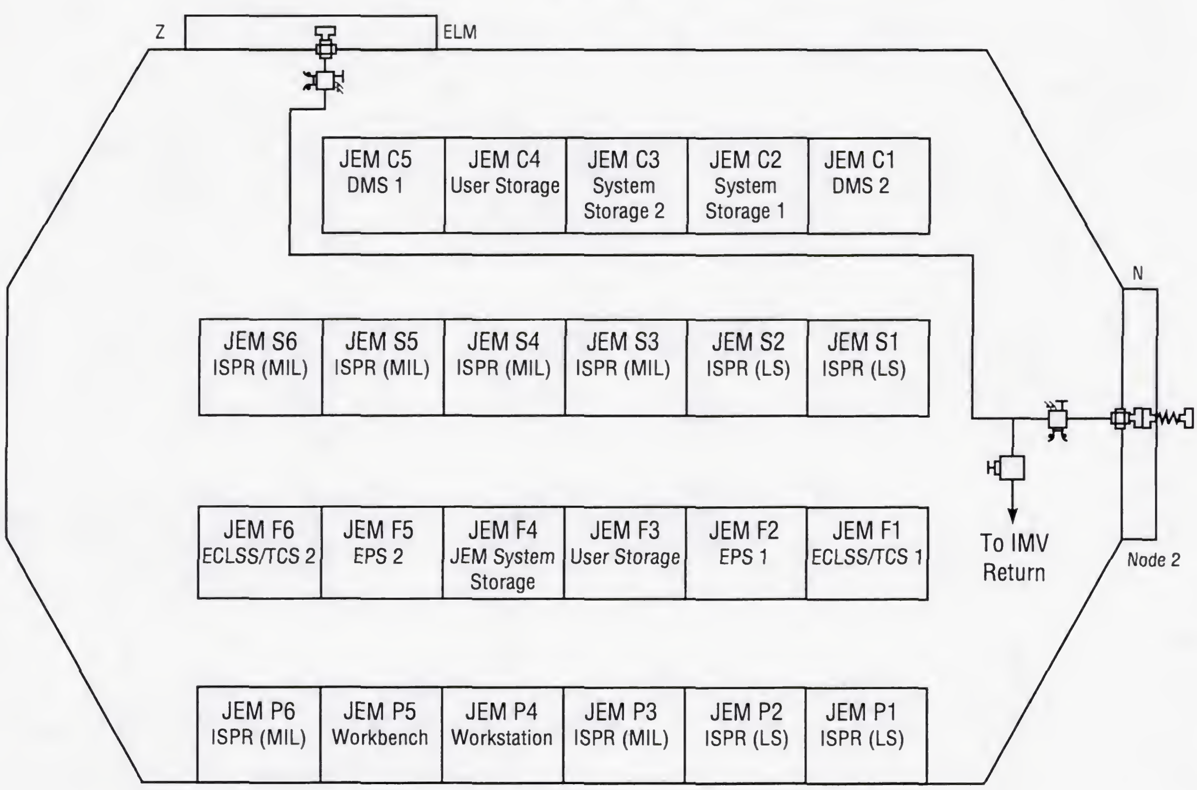


FIGURE 176.—AR subsystem schematic (continued).

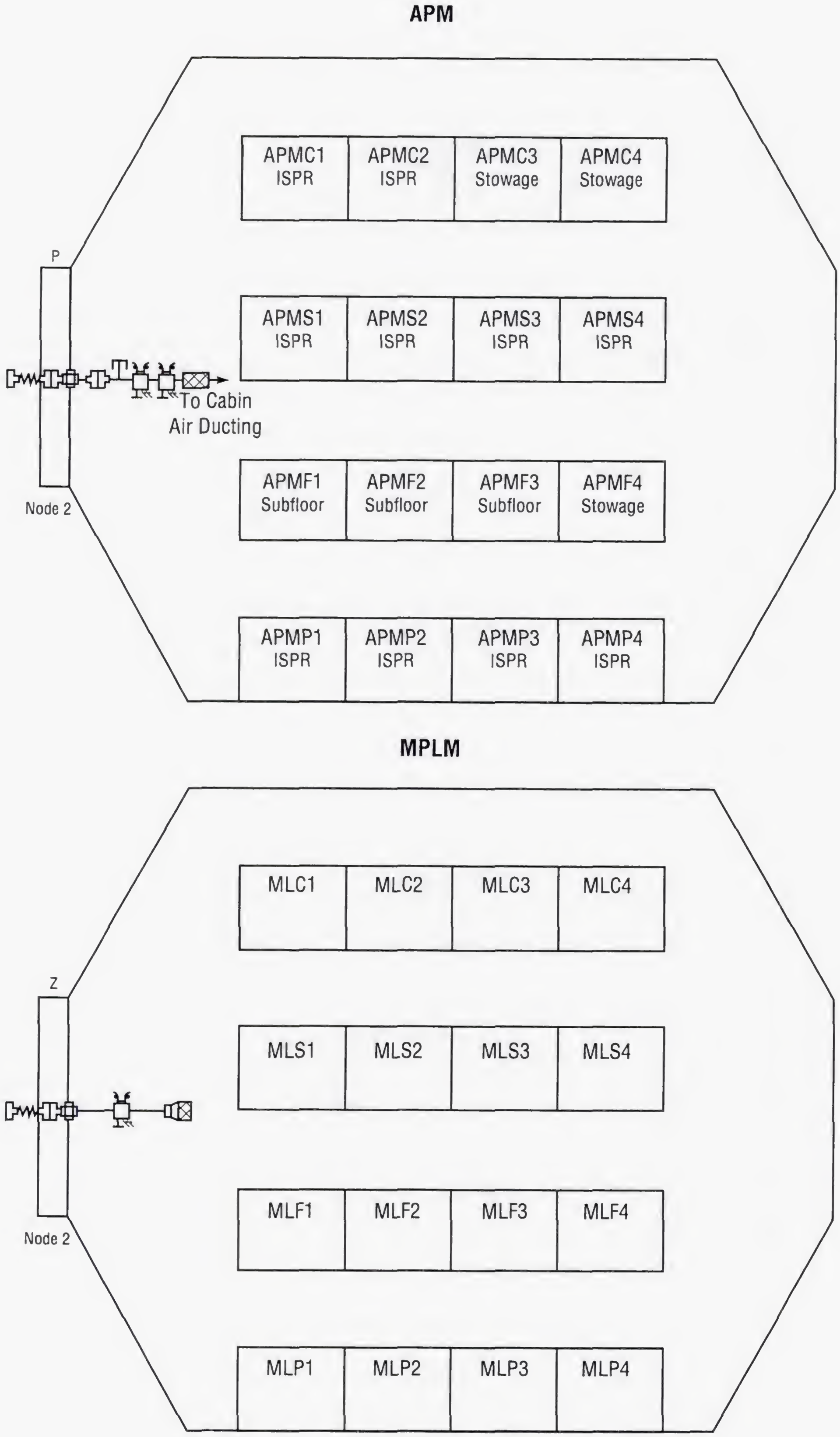


FIGURE 177.—AR subsystem schematic (continued).

3.3.2.2.1 Monitor Gaseous Contaminants

Trace contaminant monitoring is performed by the CHeCS, which is part of the USOS "crew systems" rather than ECLS.

3.3.2.3 Control Airborne Particulate Contaminants

Particulate contamination control in the cabin atmosphere is performed by a two HEPA filters in the cabin circulation loop, upstream of each CHX. These HEPA filters maintain the particulate level at class 100,000 level. Airborne particulates are removed to have no more than 0.05 mg/m^3 (100,000 particles per ft^3) with peak concentrations less than 1.0 mg/m^3 (2 million particles/ft^3) for particles from 0.5 to 100 μm in diameter. These HEPA filters are similar to those in the USOS, described in chapter II, section 3.2.3.

3.3.2.4 Control Airborne Microbial Growth

Airborne microorganisms are also controlled by the HEPA filters that control airborne particulate contaminants. The daily average concentration of airborne microorganisms is limited to <1,000 CFU/m^3 (28 CFU/ft^3).

3.3.3 MPLM AR

The MPLM AR subsystem provides atmosphere samples to the USOS for analysis and provides for depressurization of the MPLM as described in the following sections.

3.3.3.1 Control CO_2

This capability is provided by the USOS or RS via IMV.

3.3.3.2 Control Gaseous Contaminants

Primary trace contaminant control is provided by the USOS or RS via IMV. The capability to initiate depressurization of the MPLM to remove a hazardous atmosphere is provided, via the DA described in section 3.1.1.6.1.

3.3.3.2.1 Monitor Gaseous Contaminants

Trace contaminant monitoring is performed by the CHeCS, which is part of the USOS "crew systems" rather than ECLS. Atmosphere samples can be collected via the SDS (see 3.1.3.3.1).

3.3.3.3 Control Airborne Particulate Contaminants

This capability is provided by the USOS via IMV.

3.3.3.4 Control Airborne Microbial Growth

This capability is provided by the USOS via IMV.

3.4 Fire Detection and Suppression (FDS)

The FDS subsystem in the APM, JEM, and MPLM is shown schematically in figures 178–180, and is described in the following sections for each segment. The FDS equipment (smoke detectors, PFE's, and PBA's) is located in each module containing powered racks. To minimize the occurrence or spread of a fire, materials are used that are self-extinguishing or nonflammable. Also, methods of containing a fire at its source are used to limit its spread.

3.4.1 APM FDS

The APM FDS subsystem is self-contained within the APM, but communicates with the USOS C&DH subsystem, as described in the following sections.

3.4.1.1 Respond to Fire

Detection of a fire will initiate a Class I alarm and a visual indication of the fire event. The visual indication consists of activation of the fire alarm light on the C&W panel and, for ISPR's, activation of a red LED indicator on the power-kill switch of the rack panel. Fires will be suppressed by PFE's, described in chapter II, section 3.4.1.3. The PFE's will suppress a fire within 1 min of suppressant discharge by reducing the O_2 concentration to less than 10.5 percent. As a last resort, the module can be depressurized to suppress a fire.

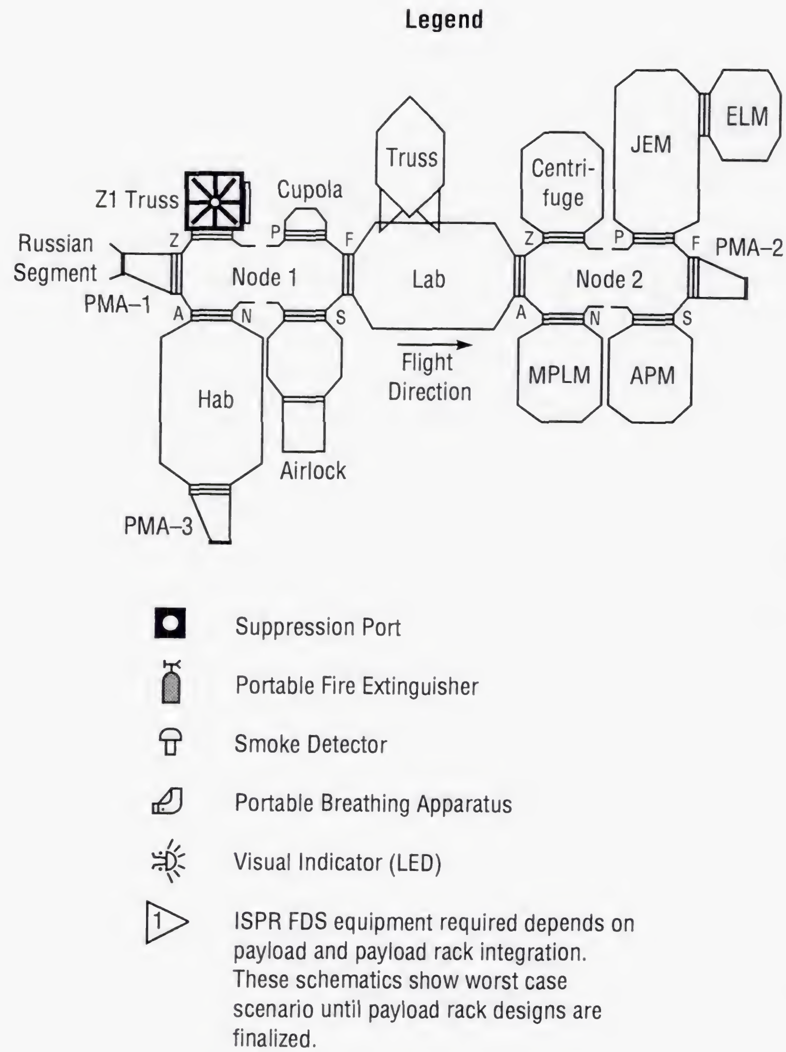


FIGURE 178.—FDS subsystem schematic.

When initiated by the crew or ground control, the APM will vent the atmosphere to space through the DA to achieve an O_2 concentration less than 6.9 kPa (1.0 psia) within 10 min. The APM can be repressurized from the USOS through the MPEV.

3.4.1.1.1 Detect a Fire Event

The APM smoke detectors are identical to the USOS smoke detectors, described in chapter II, section 3.4.1.1. Smoke detectors are located in the ventilation ducting downstream of the cabin fan and downstream of the IMV return air fan. Two detectors are at each location.

3.4.1.1.2 Isolate Fire

To isolate a fire, power is switched off to the affected location and atmospheric circulation and IMV are stopped.

3.4.1.1.3 Extinguish Fire

PFE's (described in chapter II, section 3.4.1.3) can be used to discharge CO_2 into the fire location or, if necessary, the affected module can be depressurized by the DA's. When using a PFE, it is attached to a fitting in a rack as shown in chapter II, figure 116, and the CO_2 is discharged into the rack.

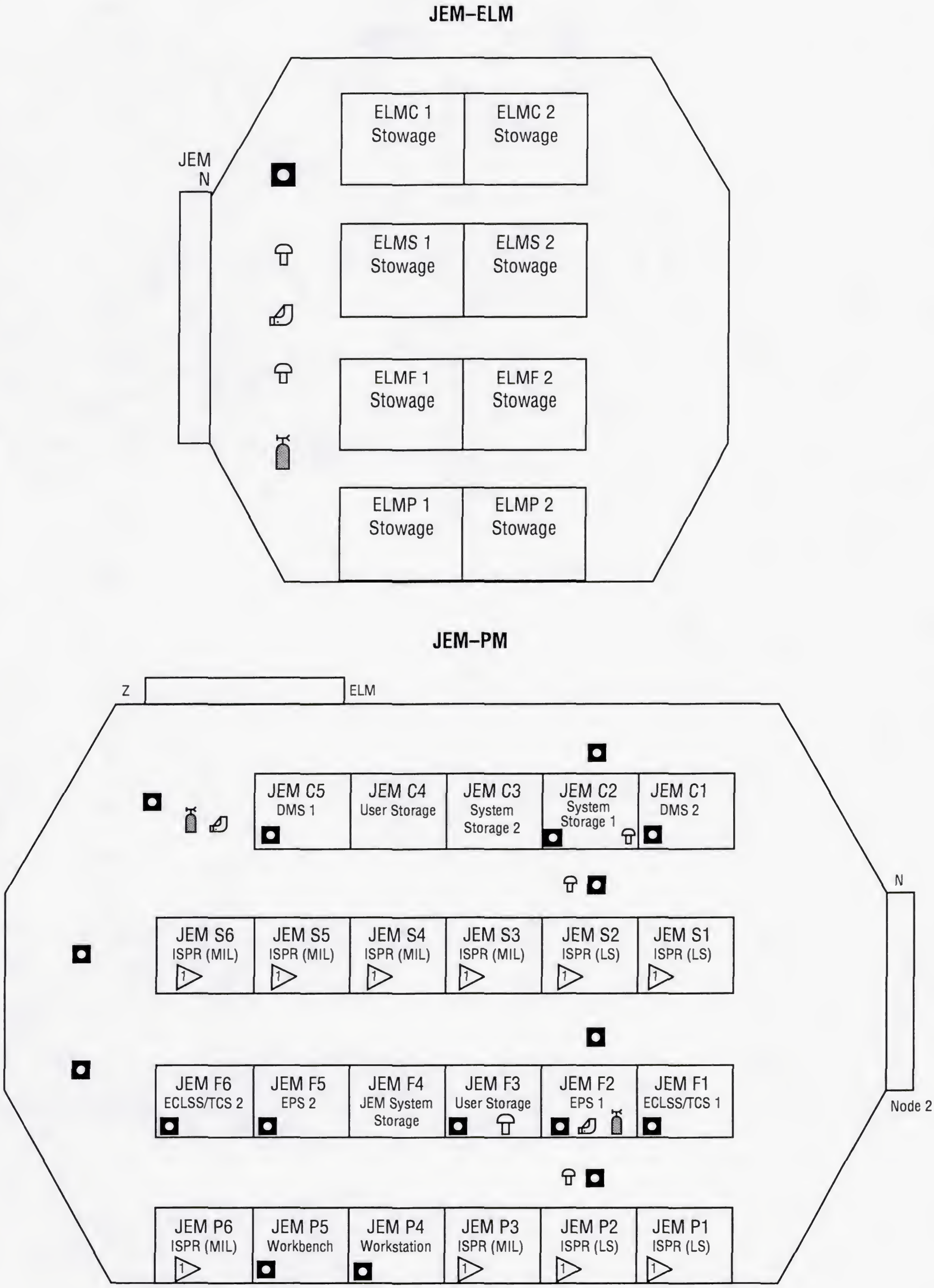
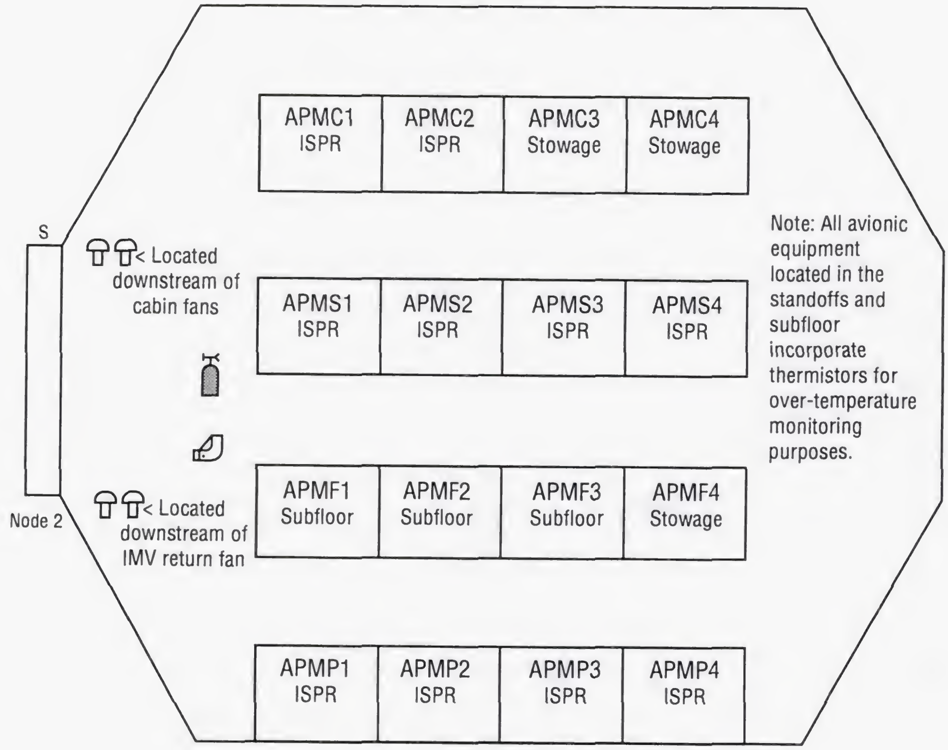


FIGURE 179.—FDS subsystem schematic (continued).

APM



MPLM

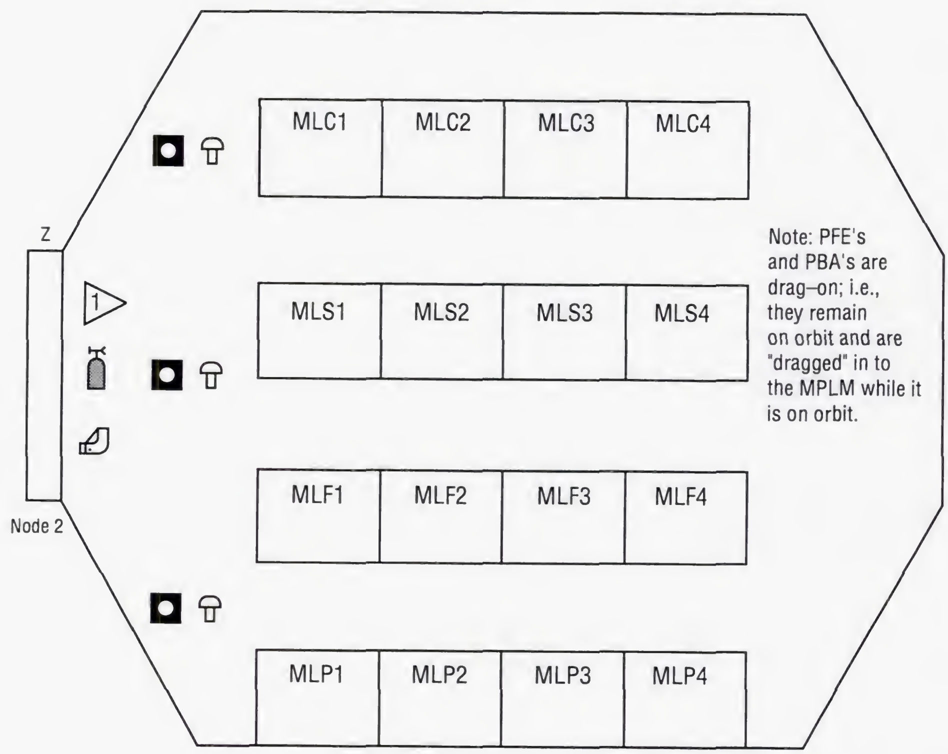


FIGURE 180.—FDS subsystem schematic (continued).

3.4.1.1.4 Recover From a Fire

Recovering from a fire is similar to recovering from a hazardous atmospheric event, described in section 3.1.1.6.

3.4.2 JEM FDS

The JEM FDS subsystem is self-contained within the JEM, but communicates with the USOS FDS subsystem. The FDS subsystem is shown schematically in figure 181. The FDS subsystem in the PM consists of the following components:

- Fire detection
  - Smoke detectors (four)
- Fire suppression
  - PFE's (two)
  - PBA's (two)
  - Fire panels (two)
  - Fire ports (TBD).

The FDS subsystem in the ELM–PS consists of the following components:

- Fire detection
  - Smoke detectors (two)
- Fire suppression
  - PFE's (one)
  - PBA's (two)
  - Fire ports (TBD).

3.4.2.1 Respond to Fire

Detection of a fire will initiate a Class I alarm and a visual indication of the fire event. The visual indication consists of activation of the fire alarm light on the C&W panel and, for ISPR's and the workstation racks, activation of a red LED indicator on the power kill switch of the rack panel. Fires will be suppressed by PFE's, described in chapter II, section 3.4.1.3. The PFE's will suppress a fire within one min of suppressant discharge by reducing the O_2 concentration to less than 10.5 percent. As a last resort, the module can be depressurized to suppress a fire.

When initiated by the crew or ground control, the JEM will vent the atmosphere to space through the DA to achieve an O_2 concentration less than 6.9 kPa (1.0 psia) within 10 min. The JEM can be repressurized from the USOS through the MPEV.

3.4.2.1.1 Detect a Fire Event

Fires are detected by smoke detectors that are essentially identical to USOS optical smoke detectors, described in chapter II, section 3.4.1.1. Detectors are distributed as follows:

- Two are located in PM System Racks (including the Remote Manipulator System (RMS) Control Workstation)
- One is located in each THC rack (for cabin air sampling)
- Two are located in ELM–PS standoffs.

3.4.2.1.2 Isolate Fire

Isolation of the fire (by removal of power and forced ventilation in the affected location) will occur within 30 sec of detection. Forced ventilation between modules will stop within 30 sec of annunciation of a Class I fire alarm and a visual indication of the fire event will be activated.

3.4.2.1.3 Extinguish a Fire

Fires will be suppressed by PFE's, described in chapter II, section 3.4.1.3. The PFE's will suppress a fire within 1 min of suppressant discharge by reducing the oxygen concentration to <10.5 percent. When initiated by the crew or ground control, the JEM will vent the atmosphere to space to achieve an oxygen concentration less than 6.9 kPa (1.0 psia) within 10 min.

3.4.3 MPLM FDS

The MPLM FDS subsystem is self-contained within the MPLM, but communicates with the USOS FDS subsystem. Preventative measures are used to minimize the effects of a fire. The time for detection and location of an anomaly, such as a fire, is instantaneous since it is based on monitoring the characteristics (current, voltage, speed, etc.) of the electrical equipment. Switching off power to the affected equipment removes the only energy source that can cause ignition. Material selection, equipment housing in metallic boxes, and the absence of forced airflow preclude the fire hazard. PBA's and PFE's are provided. Locations containing a credible fire risk have been partitioned into non-hermetically sealed compartments for FDS purposes.

3.4.3.1 Respond to Fire

Detection of a fire will initiate a Class I alarm and a visual indication of the fire event will be activated. Fires will be suppressed by PFE's, described in chapter II, section 3.4.1.3. The capability to restore the habitable environment after a fire event is present, by repressurization from the USOS via the MPEV.

3.4.3.1.1 Detect a Fire

The smoke detector in the MPLM is identical to those used in the USOS, described in chapter II, section 3.4.1.1. A smoke detector is located downstream of the cabin fan assembly (CFA), to provide the smoke detection for the cabin. In the worst case, the time needed to detect cabin smoke is about 7 min. The signal from the smoke detector will detect only smoke in the MPLM cabin. When smoke is detected, an emergency signal is sent to the USOS alerting the crew of a possible fire.

3.4.3.1.2 Isolate a Fire Event

Isolation of the fire (by removal of power and forced ventilation in the affected location) will occur within 30 sec of detection. Forced ventilation between modules will automatically stop within 30 sec of annunciation of a Class I fire alarm and a visual indication of the fire event will be activated.

3.4.3.1.3 Extinguish a Fire

Fires will be suppressed by PFE's, described in chapter II, section 3.4.1.3. The PFE's will suppress a fire within 1 min of suppressant discharge by reducing the oxygen concentration to <10.5 percent. Three fire suppression ports (FSP) (shown in fig. 182) allow access for a PFE to extinguish a fire. When initiated by the crew or ground control, the MPLM will vent the atmosphere to space to achieve an O_2 concentration <6.9 kPa (<1.0 psia) within 10 min.

3.5 Waste Management (WM)

There is no WM subsystem in the APM, JEM, and MPLM because this function is provided by the USOS and RS.

3.5.1 APM WM

The APM is not required to provide WM.

3.5.1.1 Accommodate Crew Hygiene and Wastes

This capability is provided by the USOS and RS.

3.5.2 JEM WM

The JEM is not required to provide WM.

3.5.2.1 Accommodate Crew Hygiene and Wastes

This capability is provided by the USOS and RS.

3.5.3 MPLM WM

The MPLM is not required to provide WM.

3.5.3.1 Accommodate Crew Hygiene and Wastes

This capability is provided by the USOS and RS.

3.6 Water Recovery and Management (WRM)

The WRM subsystem in the APM and JEM is shown schematically in figures 183–185, and is described in the following sections for each segment. There is no WRM subsystem in the MPLM.

3.6.1 APM WRM

The APM WRM function consists only of delivering condensate water, collected in the CHX of the THC subsystem, to the USOS water processor, in accordance with SSP 41151, with the conditions at the interface with the USOS as listed in table 36. All processing of wastewater is performed in the USOS.

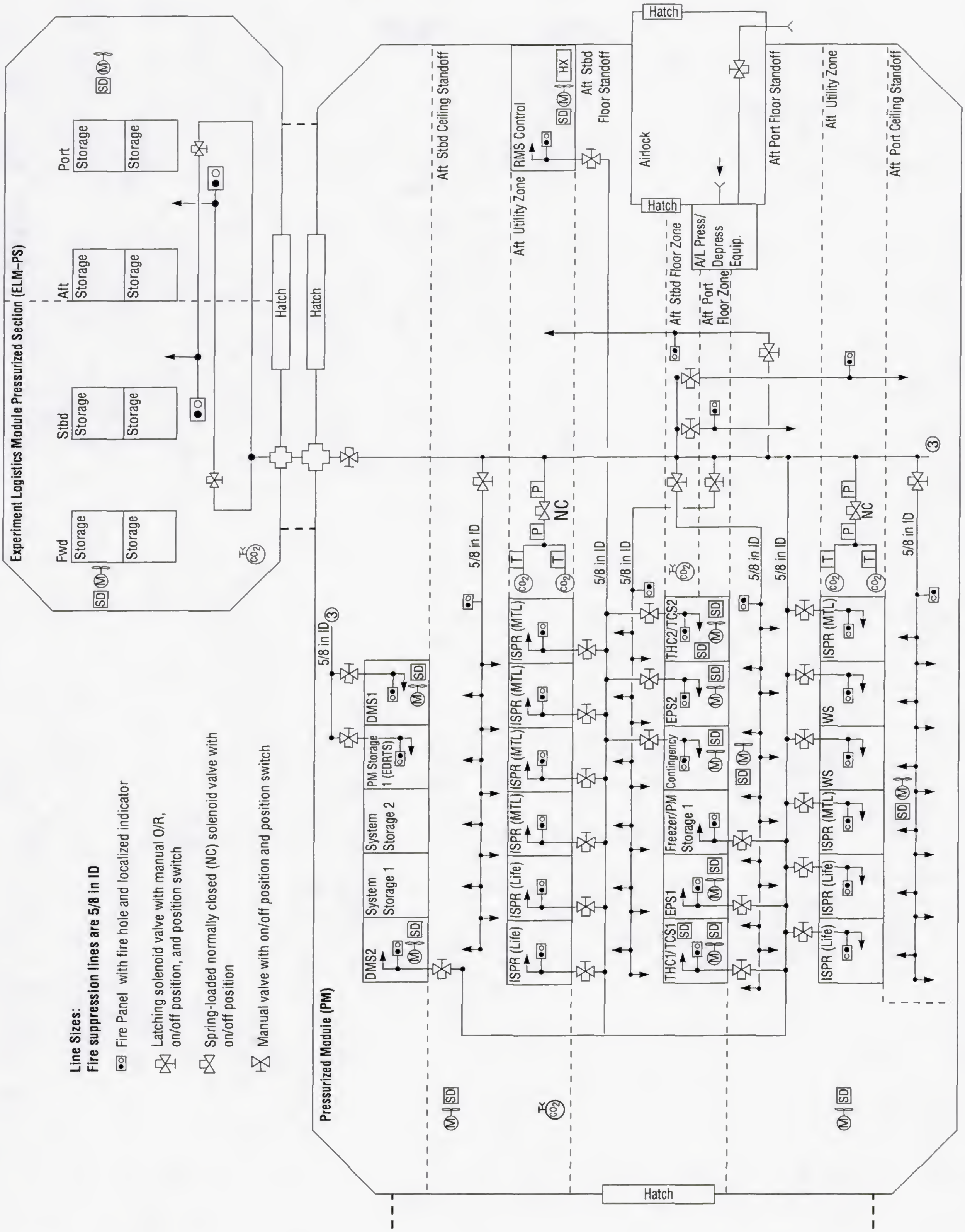


FIGURE 181.—JEM FDS schematic.

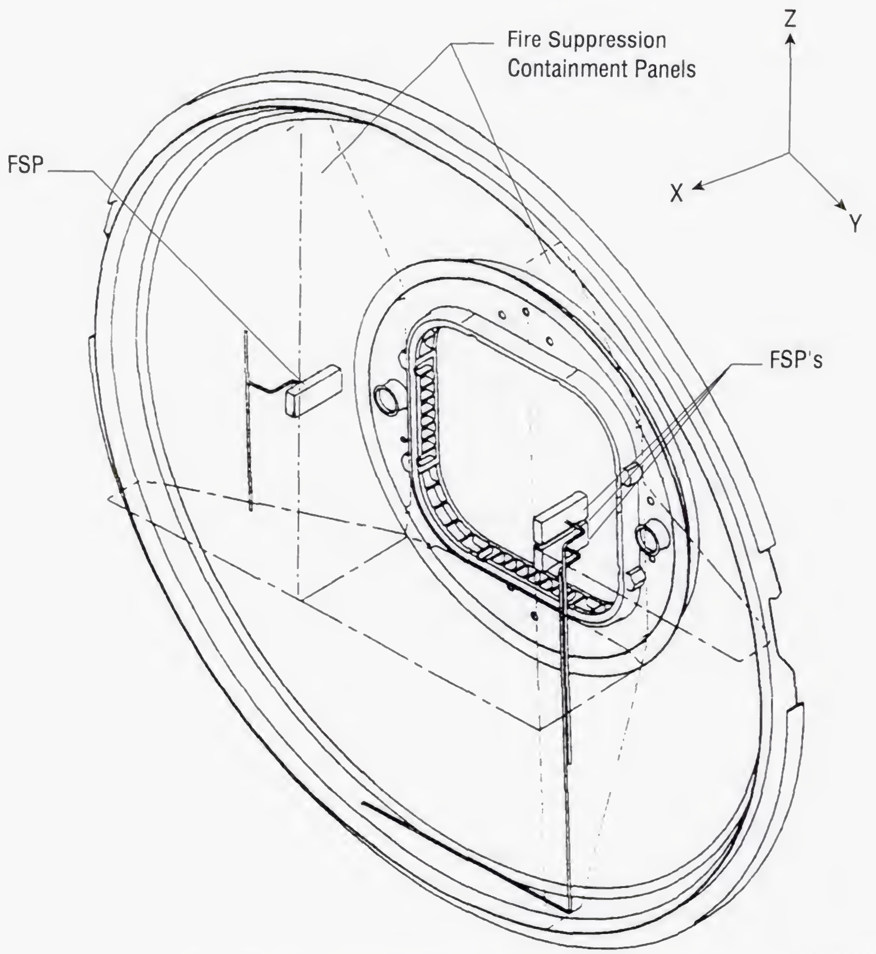


Figure 182.—MPLM Fire Suppression Ports.

3.6.1.1 Provide Water for Crew Use

This capability is provided by the USOS and RS.

3.6.1.2 Supply Water for Payloads

This capability is not required in the APM.

3.6.2 JEM WRM

The JEM WRM function consists of delivering condensate water, collected in the CHX of the THC subsystem, to the USOS water processor, in accordance with SSP 41150. All wastewater processing is performed in the USOS.

The WRM condensate delivery subsystem performs the following functions:

- Removes condensate from the PM THC units and delivers it to the USOS wastewater bus.
- Supports humidity control within the PM and ELM–PS.

The characteristics of the condensate water are listed in table 39. The WRM condensate delivery subsystem consists of the following components:

- Manual isolation valve:
  - Provides supply/isolation of condensate delivery between JEM and USOS
  - Manual valve with on/off position and position switch
  - Located in PM stbd endcone.
- Condensate lines:
  - Deliver condensate from THC units 1 and 2 to USOS wastewater bus
  - 1.27 cm (0.5 in) ID lines.

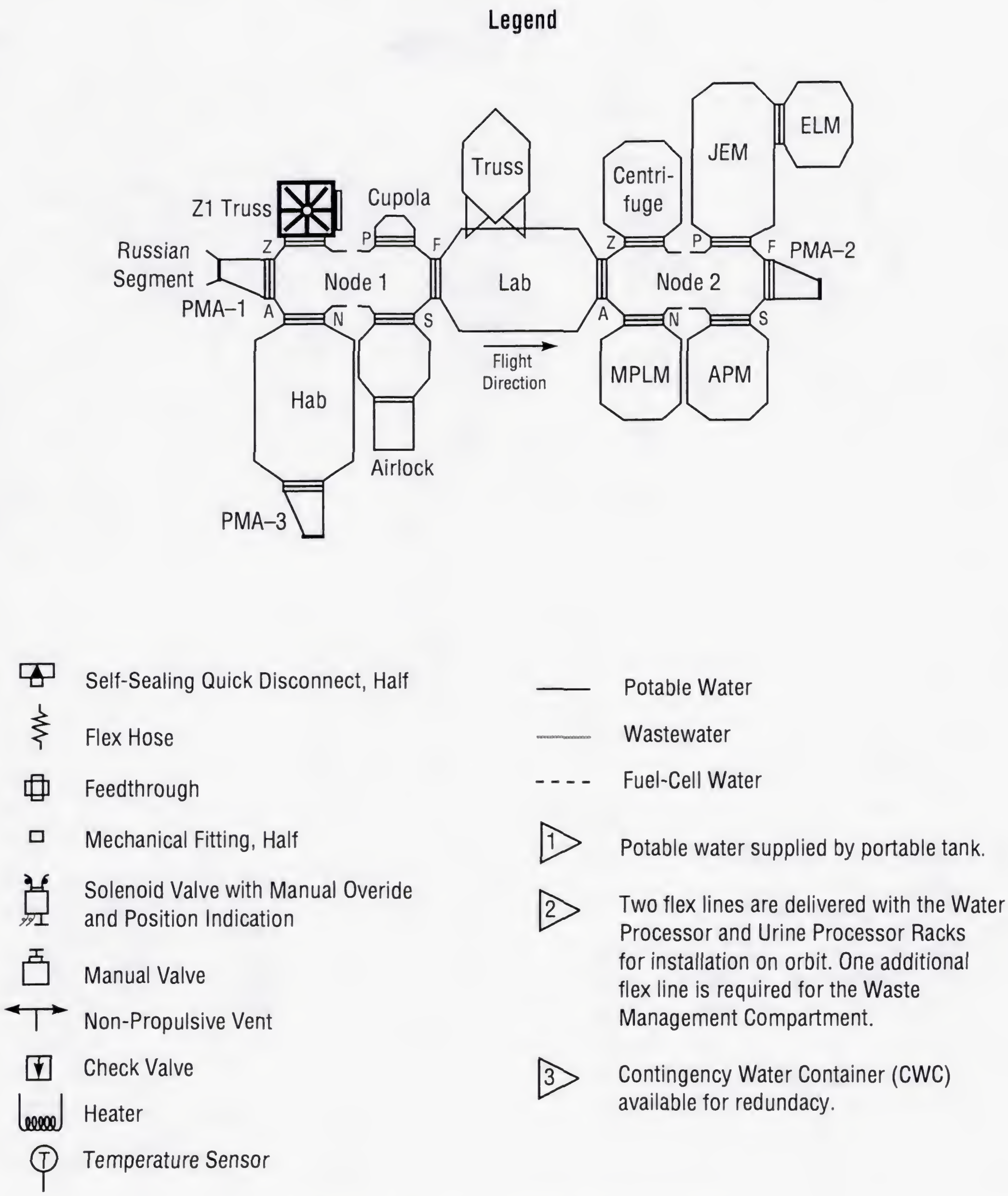


FIGURE 183.—WRM subsystem schematic.

3.6.2.1 Provide Water for Crew Use

This capability is provided by the USOS and RS.

3.6.2.2 Supply Water for Payloads

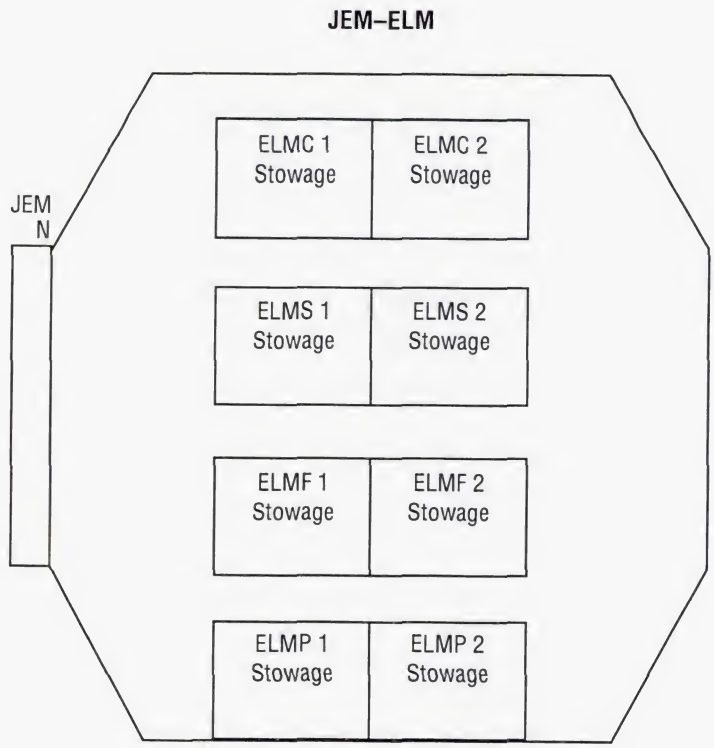
This capability is provided by the USOS.

3.6.3 MPLM WRM

There is no WRM subsystem or equipment in the MPLM.

3.6.3.1 Provide Water For Crew Use

This capability is provided by the USOS and RS.



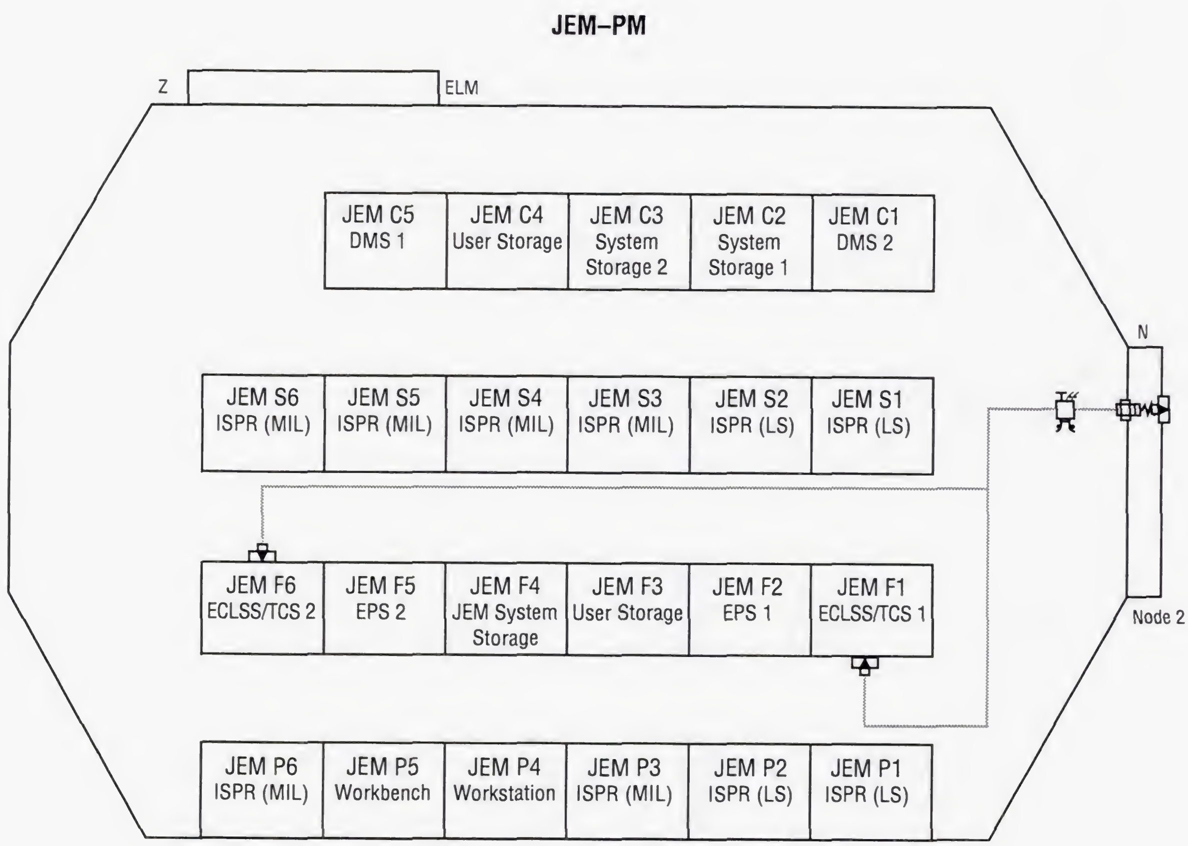


FIGURE 184.—WRM subsystem schematic (continued).

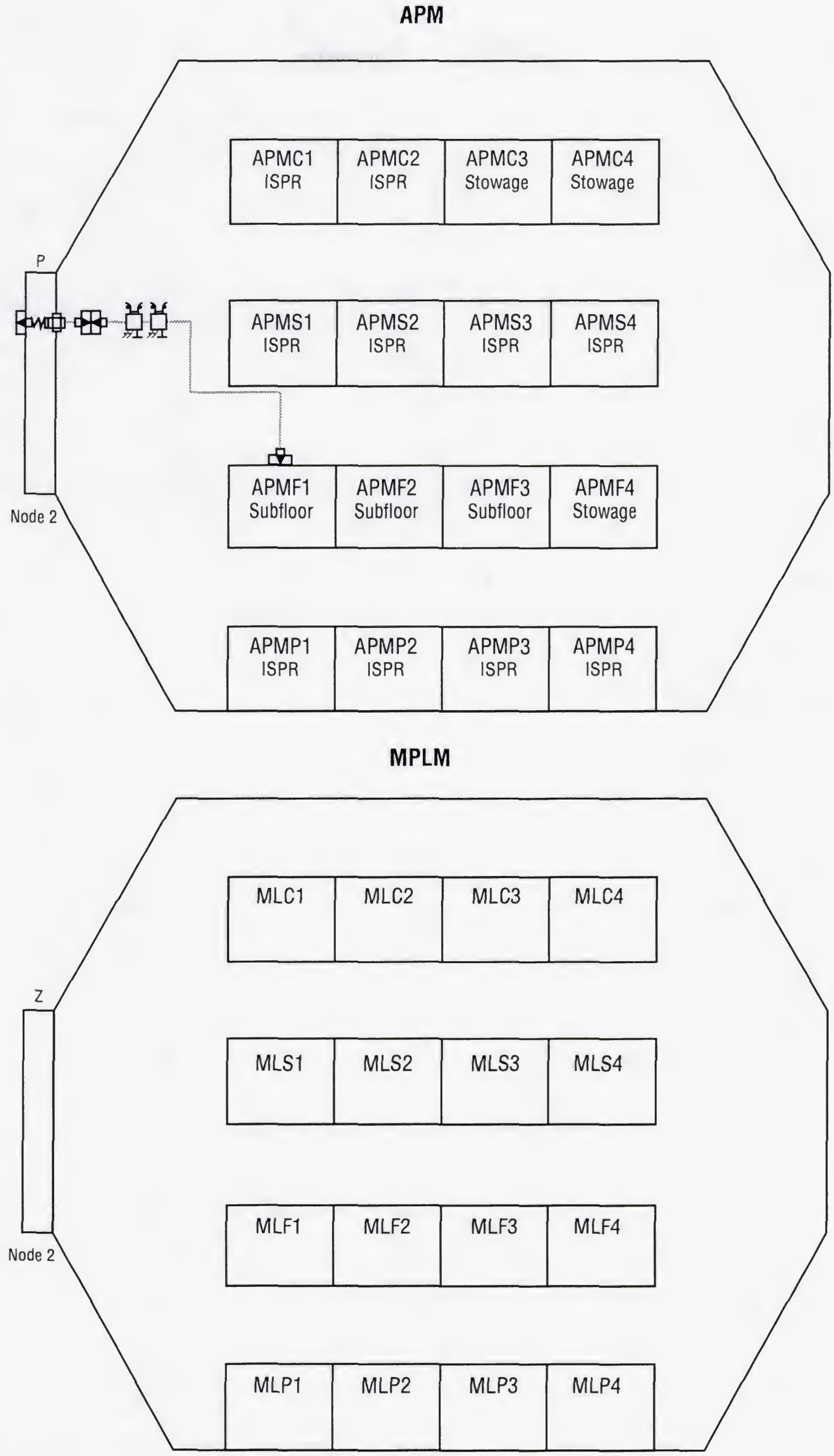


Figure 185.—WRM subsystem schematic (continued).

3.6.3.2 Supply Water for Payloads

This capability is not required because there are no active payloads in the MPLM.

3.7 Vacuum Services (VS)

The VS subsystems in the APM and JEM provide vacuum resource and waste gas exhaust services for use by payloads. No VS subsystem is required in the MPLM.

3.7.1 APM VS

The APM VS subsystem has separate vacuum resource and waste gas exhaust lines for each port and starboard payload rack, as shown in figure 186. Pressure in the vacuum lines is monitored by two types of sensors:

- Low-range pressure sensor (Pirani type) in the range 0.1 to 100 Pa (1.45×10^{-5} to 1.45×10^{-2} psia)
- High-range pressure sensor (common to P_{tot} sensor) in the range from 1 to 1200 hPa (1.45×10^{-2} to 17.42 psia).

Line repressurization is via dedicated manual valves (one per line).

3.7.1.1 Supply Vacuum Services to User Payloads

Waste gas exhaust capability is provided to all 10 active ISPR's (including the ones in the ceiling) and vacuum resource is provided to the 8 lateral ISPR's. The vacuum lines are made of stainless steel. Heaters on the VS venting devices are controlled via a dedicated redundant electronic unit (HCU) mounted external to the APM. The HCU monitors relevant temperature sensors and commands the heaters.

The VS subsystem is compatible with gases released by ISPR experiments and their relevant pressures (up to 276 kPa (40 psia)). The self-sealing QD's at the interface with the ISPR are identical to those used on the USOS. The design is zero-failure tolerant.

3.7.1.1.1 Vacuum Resource

The vacuum resource line provides a vacuum of 0.16 Pa (2.3×10^{-5} psia) to the payload rack interface. Gases are evacuated to space via a device located on the aft endcone. The vacuum function can only be used after the payload chamber has been vented.

3.7.1.1.2 Waste Gas Exhaust

The waste gas exhaust line is sized to evacuate an experiment chamber volume of 100 L (3.53 ft^3) at 21 °C (70 °F) and 1×10^5 Pa (14.5 psia) to 0.13 Pa (1.9×10^{-5} psia, 1×10^{-3} torr) in less than 2 hr. The vacuum level in the chambers can be maintained at 0.13 Pa (1.9×10^{-5} psia, 1×10^{-3} torr) with a total gas load of 0.10 Pa/sec (0.77×10^{-3} torr/sec). The VS venting device is the same as the depressurization assembly (see section 3.1.1.6.1).

The waste gas exhaust lines include normally-closed solenoid valves to provide waste gas exhaust access at ISPR locations. These valves are spring-loaded closed solenoid valves with manual override, on/off position indicators, and a position switch. Gases are vented to space via a device located at the forward endcone.

3.7.2 JEM VS

The JEM VS subsystem has separate vacuum resource and waste gas exhaust lines for each port and starboard payload rack.

3.7.2.1 Supply Vacuum Services to User Payloads

Waste gas exhaust and vacuum resource capability is provided to active ISPR's.

3.7.2.1.1 Vacuum Resource

No information is presently available.

3.7.2.1.2 Waste Gas Exhaust

The waste gas exhaust subsystem removes waste gases from payloads. Materials in the wetted surfaces of the waste gas subsystem that are in contact with user payload waste gases are limited to: stainless steel (321 and 440), titanium 6 AL–4V, fluorocarbon rubber (Viton, in the Pirani gauge transducer), glass, platinum iridium alloy, gold-plated brass (in the cold cathode transducer), ceramic, aluminum (in the cold cathode transducer), and tetrafluoroethylene (Teflon™). The waste gas subsystem is compatible with acceptable gases as listed

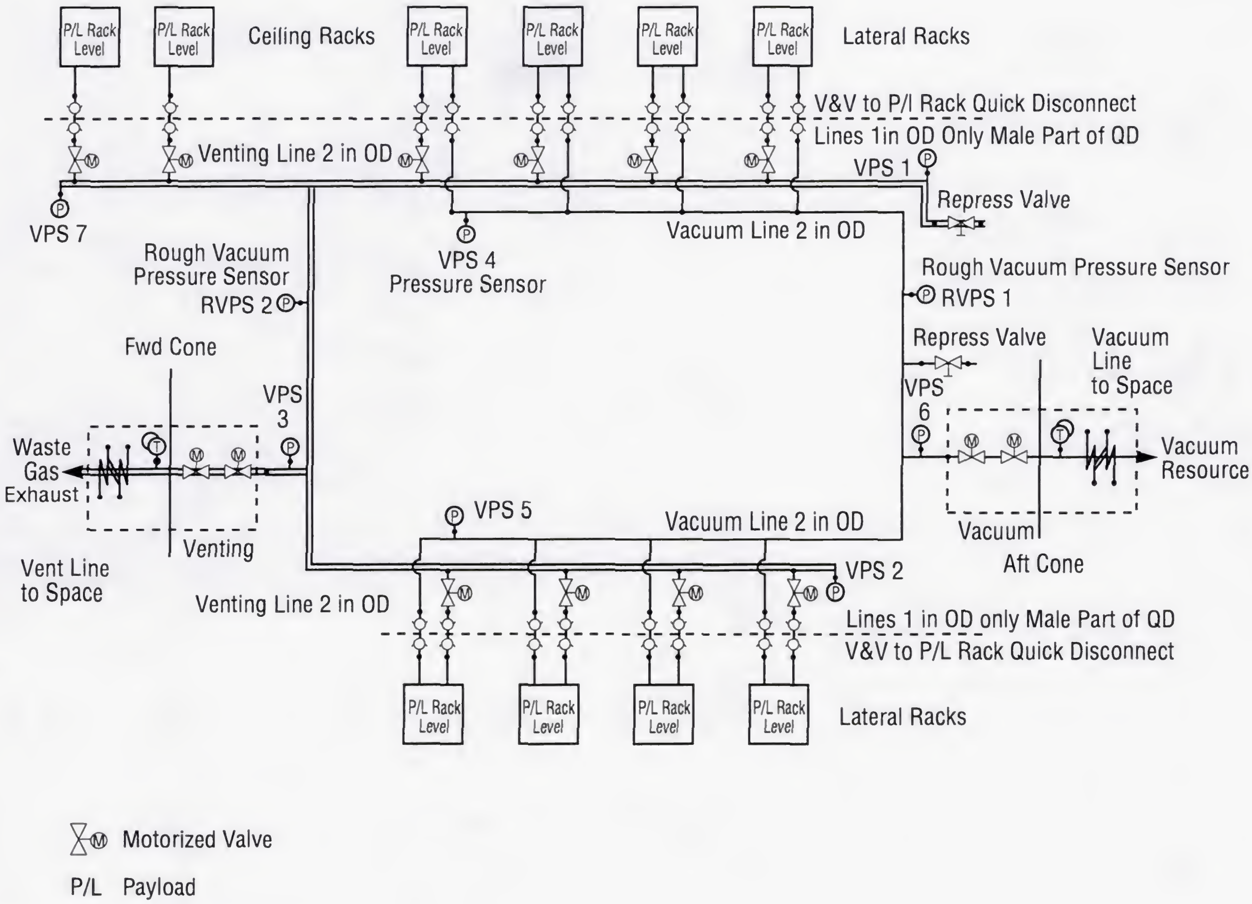


FIGURE 186.—APM vacuum services subsystem functional schematic (from ECLSS TIM, APM ECLSS presentation, Houston, TX, 24 to 28 July 1995).

in table 46. Payload gas contaminants compatible with the wetted materials of the waste gas subsystem and in concentrations compliant with the *ISS* external contamination control requirements (SSP 30426) are also acceptable for waste gas subsystem use.

TABLE 46.—*JEM VS subsystem acceptable gases (ESA/ASI/NASA ECLS TIM, 24 to 28 July 1995, JSC).*

CO (pp < 5Pa). Nontoxic waste gas or nontoxic and nonreactive mixtures of these gases: • Nitrogen • Cabin atmosphere • Argon (Ar) • Krypton • Xenon • Helium • CO_2 (pp <7.6 torr (1.01 kPa)) • O_2 (pp <23.3 kPa) • H_2 (pp <3.3 kPa)

3.7.3 MPLM VS

This capability is not required in the MPLM.

3.7.3.1 Supply Vacuum Services to User Payloads

This capability is not required in the MPLM.

3.8 EVA Support

EVA support is not required of the APM, JEM, or MPLM.

3.8.1 APM EVA Support

This capability is not required in the APM.

3.8.1.1 Support Denitrogenation

This capability is not required in the APM.

3.8.1.2 Support Service and Checkout

This capability is not required in the APM.

3.8.1.3 Support Station Egress

This capability is not required in the APM.

3.8.1.4 Support Station Ingress

This capability is not required in the APM.

3.8.2 JEM EVA Support

This capability is not required in the JEM.

3.8.2.1 Support Denitrogenation

This capability is not required in the JEM.

3.8.2.2 Support Service and Checkout

This capability is not required in the JEM.

3.8.2.3 Support Station Egress

This capability is not required in the JEM.

3.8.2.4 Support Station Ingress

This capability is not required in the JEM.

3.8.3 MPLM EVA Support

This capability is not required in the MPLM.

3.8.3.1 Support Denitrogenation

This capability is not required in the MPLM.

3.8.3.2 Support Service and Checkout

This capability is not required in the MPLM.

3.8.3.3 Support Station Egress

This capability is not required in the MPLM.

3.8.3.4 Support Station Ingress

This capability is not required in the MPLM.

3.9 Other ECLS Functions

Additional ECLS functions are provided in the APM and JEM, as described in the following sections.

3.9.1 APM Other ECLS Functions

Other ECLS functions include providing nitrogen gas to user payloads.

3.9.1.1 Gases to User Payloads

The N_2 supply subsystem in the APM is shown schematically in figure 187. N_2 is supplied to all 10 active ISPR's and to 2 TCS accumulators for their active control. The interface conditions are:

- Operating Pressure
  - 620 to 827 kPa (90 to 120 psia) with the USOS
  - 517 to 827 kPa (75 to 120 psia) at the ISPR
- Maximum Design Pressure
  - 1378 kPa (200 psia)
- Temperature
  - 17.2 to 45 °C (63 to 113 °F)

- Flowrate
  - 0 to 16.3 kg/hr (0 to 36 lb/hr)
- Purity
  - 95 percent by volume.

3.9.2 JEM Other ECLS Functions

Other ECLS functions include providing N_2, CO_2, He, and Ar gases to user payloads.

3.9.2.1 Gases to User Payloads

The JEM provides several gases to user payloads including: N_2, CO_2, He, and Ar.

Equipment to support supplying these gases consists of valves, sensors, tanks, and other components, listed below:

- Latching solenoid valves
  - Provide N_2 isolation/supply to ISPR, freezer, and ITCS locations
  - Valves have manual override with on/off position indication and a position switch
- Manual valves
  - Provide isolation of N_2, waste gas, and vacuum lines
  - Valves have on/off position indicators
- Pressure and temperature sensors
  - Analog vacuum sensors located on waste gas vent line and on vacuum vent line (two sensors)
  - Analog pressure sensors located on N_2, waste gas vent, and vacuum vent lines
  - Temperature sensor located on waste gas vent line
- Common gas supply equipment
  - Tanks and valves to store and distribute CO_2, Ar, and He to PM racks
  - Two CO_2 tanks, two He to tanks, and two Ar tanks
  - CO_2 provided to ISPR (life science experiments) and freezer locations
  - He and Ar provided to ISPR (materials science experiments) locations.

3.9.2.2 Experiment Airlock (EAL) Pressurize/Depressurize Equipment

The EAL equipment performs the following functions:

- Controls depressurization and repressurization of the JEM EAL.
- Obtains pressurization gases from the cabin air return duct.
- Pumps EAL atmosphere into the cabin air return duct.

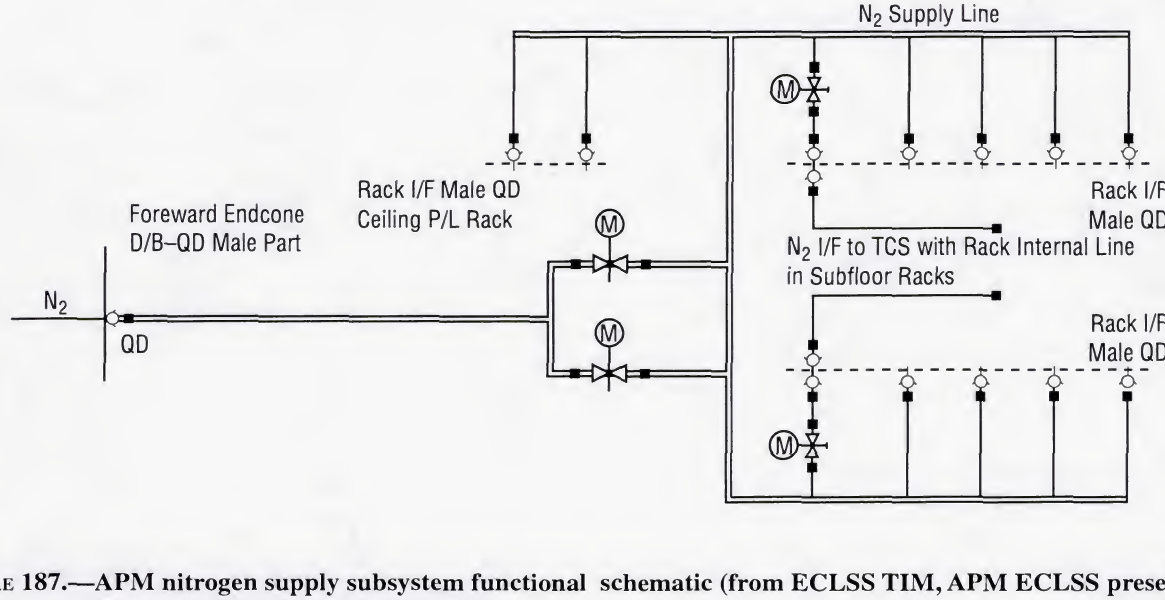


FIGURE 187.—APM nitrogen supply subsystem functional schematic (from ECLSS TIM, APM ECLSS presentation, Houston , TX, 24 to 28 July 1995).

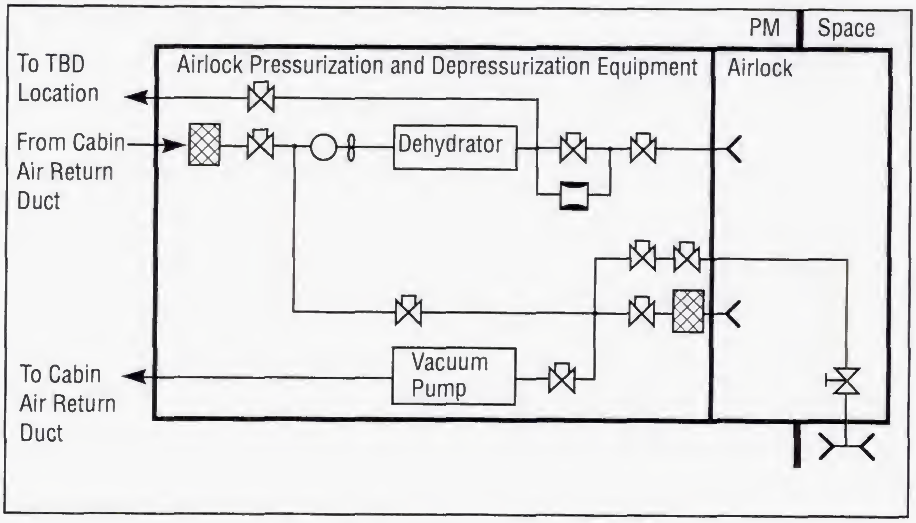


Figure 188.—EAL schematic.

The EAL (shown schematically in fig. 188) consists of the following components:

- Vacuum pump:
  - Supports EAL pump-down
  - Receives cooling from MTL
- Fan:
  - Propels air through the dehydrator
  - May support air circulation within the EAL
- Dehydrator:
  - Provides dry pressurization gases to the EAL
- Solenoid and manual valves:
  - Control depressurization/repressurization routing and provide isolation
  - Manual valve supports redundant depressurization capability
- Filters and flow restrictors:
  - Filter air from cabin air return duct and EAL interior.

3.9.3 MPLM Other ECLS Functions

This capability is not required in the MPLM.

4.0 Safety Features

Safety features that are designed into the APM, JEM, and MPLM include overpressure relief, smoke detection, and redundancy of critical components, as described in previous sections of this report. These features are derived from failure tolerance requirements, fire propagation requirements, and reliability requirements. Examples of some of these safety features are described in the following sections.

4.1 PPRA

The PPRA includes redundant valves to provide single failure tolerance for both opening and closing of the valves. The PPRA is described further in section 3.1.1.3.

4.2 Pressure Shell Penetrations

Penetrations of the pressure shell, such as for the DA, PPRA, NPRA, and vacuum and venting devices, have two redundant O-ring seals for sealing against leakage, as shown in figures 189 and 190.

4.3 Failure Tolerance

The failure tolerance requirement for IMV is one-failure tolerant for the APM. (NASA has no failure tolerance requirements specifically for IMV.)

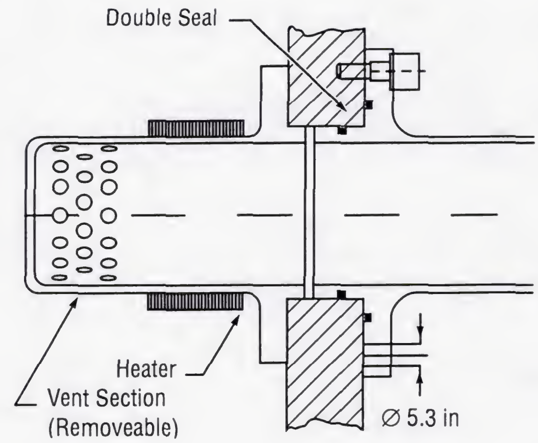


FIGURE 189.— APM shell penetration seals (from ECLSS TIM, APM ECLSS presentation, Houston, TX, 24 to 28 July 1995).

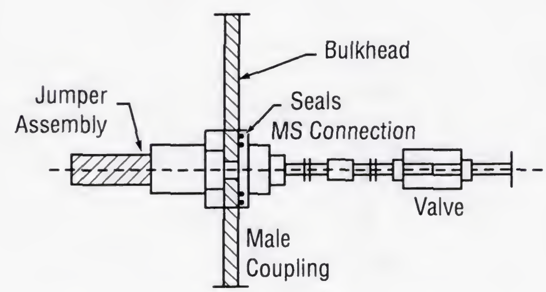


FIGURE 190.—APM shell penetration seals (continued).

5.0. Maintenance Procedures

The ECLS equipment is designed to be maintainable by replacement or repair of components. Equipment is mounted in racks such that expendable components can be easily accessed and critical components can be removed, or the entire rack can be replaced. For example, each ORU of the Condensate Water Separator Assembly (CWSA) can be replaced without removing the entire assembly. Fluid connections generally use quick disconnectors that preclude leakage. Some maintenance procedures can be performed without removing equipment, such as the THC CHX dryout procedure described below.

5.1 APM CHX Dryout Procedure

As moisture condenses in the CHX, microorganisms may grow and contaminate equipment, especially the CHX, slurper line, and CWSA. To eliminate or reduce this growth the CHX is periodically dried. The dryout period lasts at least 8 hr each week, to completely dry the CHX, slurper line, and CWSA. Dryout involves removing all humidity from a potential biolayer. The procedure for drying out the CHX involves the following steps:

- CHX core and slurper dryout: requires about 1 hr of full airflow provided by the cabin fan and the WS unit, without coolant water flow to avoid condensation.
- WS unit dry-out: requires about 4 hr with 85 m^3/hr (50 cfm) airflow provided by the cabin fan and the WS unit.
- Steady state dryout: requires about 2 hr, with 85 m^3/hr (50 cfm) airflow provided by the cabin fan and the WS unit.

The total minimum time required for dryout at the given flowrates is about 8 hr. There is no need to increase the air stream temperature with respect to its nominal value, because of the antimicrobial coating that minimizes the biological growth in the CHX.

The effect of the dryout period is a reduction in heat dissipation from the APM to minimum levels during dryout. This will result in the need to stop or greatly reduce the activity of payloads that generate heat during the 8-hr period required for dryout.

5.2 APM CHX Core Replacement Procedure

At the end of the 5-yr lifetime of the CHX cores, it will be necessary to replace them with new cores. The procedure for replacing the CHX core #1 or core #2 involves the following steps:

- Place the CHX core to be replaced in the "dryout" mode, with the other core active. Stop water flow in the core to be replaced by switching off the appropriate valves.
- Increase the water inlet temperature set point from 5 to 9 °C (41 to 48 °F).
- Stop the airflow through the CHX core to be replaced via a slide gate upstream of the core and close the corresponding path of the TCV.
- Replace the CHX core with the new CHX core.
- Remove the slide gate and restore the nominal conditions.
- Return the old CHX core to Earth.

6.0 Emergency Procedures and Failure Responses

Emergency situations require quick, effective responses to minimize harm to the crew and damage to equipment. Some of the emergency situations and responses are summarized below. More extensive information is provided in other documents.

6.1 Fire in the APM

After detection of smoke and the activation of the fire alarm, the response will be:

- Removal of power from the affected zone.
- Removal of IMV (switching off fans).
- Possible use of PFE's.
- APM depressurization as a last resort (to reach a ppO_2 <70 hPa (<1 psia) in <10 min).

6.2 Fire in the JEM

The fire alarm can be activated by the smoke sensors or by pressing the FIRE button on the C&W panel. A signal is sent to the USOS identifying the activated sensor. The C&W panels in the other modules activate the FIRE light, an audible alarm is sounded, and a message is sent to the laptop computers indicating the module and detector where the fire was detected. Both Node 2 IMV valves that face the JEM will be closed.

6.3 Fire/Emergency in the MPLM

As a general rule, the malfunction or loss of MPLM powered equipment is classified as a warning. Upon detection of the malfunction, a warning signal is sent to the USOS to alert the crew that a failure of powered equipment has occurred and further investigation by the crew is needed for verification. At the same time, power is automatically removed from the affected equipment. The removal of power is considered sufficient to ensure fire suppression, so the response time required is not so stringent as to require an emergency signal. After notification, the crew is in charge to investigate whether the malfunction was due to equipment failure or fire, and proceed accordingly.

In the event of malfunction or loss of a PDB or MDM, an Emergency signal is sent to the USOS to alert the crew. This situation is considered an emergency because the PDB and MDM cannot be automatically deactivated and prompt intervention by the crew is required to switch off the PDB or MDM. Because failure of a PDB or MDM can lead to a total loss of communication between the MPLM and USOS, which would prevent an alarm signal from being sent to the USOS, the USOS will signal an alarm in the event of loss of communication with the MPLM, as detected by the C&DH software. This is independent from any smoke detector signals.

6.4 PPRA Failure Scenario

Upon detection of undesired opening, or failure to close, of the pneumatic valve, the USOS signals the avionics system, which then commands the motorized valve to close to prevent further depressurization of the pressurized module. In order to provide single-failure tolerance for failure to open, a second, redundant assembly is present. The motorized valves are nominally unpowered, to improve reliability. Manual override of the motorized valves is implemented to disable or re-enable the pneumatic valves after loss of the command capability of the motorized valves. In the event that the PPRA remains open despite attempts to close it, the module would be evacuated and sealed until repairs are made.

6.5 APM Water Separator Failure

In the event of failure of a water separator in the APM CCAA, the failed WS could not be replaced until the next resupply mission (180 days maximum in case a mission is skipped), since no spares are stored on orbit. Failure scenarios that have been considered include:

- During CHX core #1 dryout, WS #2 fails.
- During CHX core #1 operation, WS #1 fails.

The consequences include:

- Stopping the THC function for 8 hr every week to dry out the CHX core #1 and switching off the heat generating payloads to avoid thermal control problems.
- CHX core #2 can be activated to recover, but will then need to be dried out each week.

6.6 Depressurization of the APM, JEM, or MPLM

In the event that the APM, JEM, or MPLM lose pressure (either accidentally or intentionally to remove contaminated atmosphere or to suppress a fire) the Node 2 hatch to the affected module must be closed to prevent depressurization of other modules. This also applies to the Node 1 hatch if the MPLM is depressurized while it is attached to Node 1. As shown in figure 191, the hatch on the pressurized side of the vestibule (i.e., Node 1 or 2) is closed rather than the hatch on the depressurized module. This ensures that atmospheric pressure is helping to maintain a tight seal.

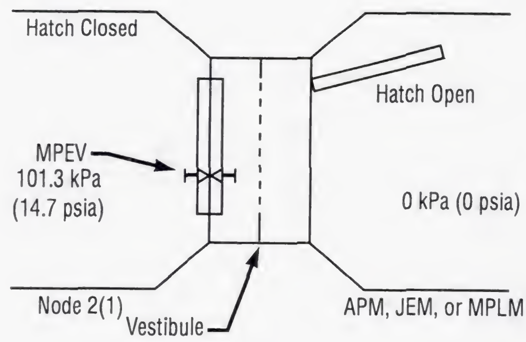


FIGURE 191.—Hatch positions when the APM, JEM, or MPLM is depressurized.

BIBLIOGRAPHY

CHAPTER I: LIVING TOGETHER IN SPACE: THE DESIGN AND OPERATION OF THE LIFE SUPPORT SYSTEMS ON THE *INTERNATIONAL SPACE STATION*

"Ames to Buy Station Centrifuge, Biological Research Facility," *Space Business News*, 29 November, 1995.

D684–10210–01, "Respond to Emergency Conditions Capability Description Document," Boeing, 1 November, 1995.

D684–10508–3–1, "Environmental Control and Life Support (ECLS) Architecture Description Document, Volume 3, ECLS Integration and Planning, Book 1 Verification Plan," Revision A, Boeing, 31 May, 1996.

"ECLS Verification Working Group, Lab Verification Plan," Boeing PG–3, 24 May, 1996.

"ESA/ISA/NASA ECLS TIM Minutes," Technical Interchange Meeting, JSC, Houston, TX, 24–28 July, 1995.

Interim Design Review 1 presentation by Dr. Grigorov, 22 March, 1995.

"Mini-Pressurized Logistics Module PDR Data Package," Alenia Spazio S.p.A., 1993.

"Mini-Pressurized Logistics Module," Alenia Spazio, S.p.A., presentation at JSC, Houston, TX, May, 1996.

MLM–RP–AI–0019. "MPLM Baseline Configuration Report," Alenia Spazio, S.p.A., 30 April, 1996

MLM–TN–AI–0185, "Mini-Pressurized Logistics Module," Alenia Spazio, S.p.A., 7 May, 1996.

S683–29523D, "Prime Item Development Specification for United States Laboratory," 28 March, 1995.

Saiidi, Mohammed, "ECLS Verification Working Group, Introduction," Boeing, 3–5 June, 1996.

Shibanov, G.P., ed., "English-Russian Dictionary on Spacecraft ECLSS," NPO Energia, 1994.

SSP 30255, "Baseline Configuration Document, Volume 2: Flight Element Configurations, Part 6: ESA Columbus Attached Pressurized Module," Draft 1, 25 May, 1993.

SSP 41000B, "System Specification for the *International Space Station* Alpha: Type 1," 1 November, 1994.

SSP 41160, "Segment Specification for the European Space Agency Attached Pressurized Module," 22 March, 1994.

SSP 41162B, "Segment Specification for the United States On-Orbit," 28 March, 1995.

SSP 41163, "Russian Segment Specification," 27 September, 1994.

SSP 41164, "Italian Mini-Pressurized Logistics Module Segment Specification," 19 March, 1994.

SSP 41165, "Segment Specification for the Japanese Experiment Module," 9 March, 1994.

SSP 42007, "United States On-Orbit Segment to Italian Mini-Pressurized Logistics Module Interface Control Document," Revision D.

SSP 42121, "U.S. On-Orbit Segment Pressurized Mating Adapter-1 to Russian Segment FGB Interface Control Document Part 1," 26 August, 1994.

SSP 50037, "Baseline Configuration Document," multiple volumes, 1995 dates for each volume.

CHAPTER II: THE UNITED STATES ON-ORBIT SEGMENT AND ITS ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM

"Atmosphere Revitalization Subsystem Description MTC Configuration, Rev A," D683–15003–1, Boeing Defense and Space Group, 26 February 1993.

D683–15007–1, "Atmosphere Control and Supply Subsystem Description MTC Configuration," Boeing, Rev. A, March 1993.

D684–10203–01, "Control Atmospheric Pressure Capability Description Document," Boeing, 8 August 1995.

D684–10204–01, "Condition Atmosphere Capability Description Document," Boeing, 8 August 1995.

D684–10210–01, "Respond to Emergency Conditions Capability Description Document," Boeing, 8 August 1995.

D684–10216–01, "Control Internal Carbon Dioxide and Contaminants Capability Description Document," Boeing, 8 August 1995.

D684–10217–01, "Provide Water Capability Description Document," Boeing, 8 August 1995.

D684–10508, ECLS Architectural Description Document, Volume 3, ECLS Integration and Planning Book 1, Verification Plan, 31 May 1996.

D684–10508–1, "Environmental Control and Life Support System (ECLSS) Architectural Description Document," Boeing Company, 23 March 1994.

Limerco, Thomas; Jay Cross; John Brokenshire; Colin Cumming; Gary Eiceman; Ed Overton; Ken Carney; and John James: "A Volatile Organic Analyzer for Space Station: Description and Evaluation of a Gas Chromatograph/Ion Mobility Spectrometer," paper number SAE 921385, 22nd International Conference on Environmental Systems, Seattle, WA, July 13–16, 1992.

LMSC/F369707, Rev. E, Vol II, "Maintainability Program Source Data, Trace Containment Control Subassembly," Lockheed Missiles and Space Company, Inc., Space Systems Division, 4 August 1992.

McKinnie, James M., "Russian-US Life Support Software Interaction," U.S.-Russian Technical Interchange Meeting #15, JSC/MOD, 14 September 1995.

Perry, Jay, "Analysis of the Capability of the U.S. and Russian Trace Contaminant Control System to Meet Cabin Atmosphere Quality Standards," MSFC memo ED62(36–94), 16 August 1994.

Presentations from the ECLSS technical briefing, Johnson Space Center, Houston, TX, 2 March 1995.

Presentations from the ECLSS technical briefing, Johnson Space Center, Houston, TX, 12 October 1994.

"Space Station Freedom, Temperature and Humidity Control (THC) Subsystem Critical Design Review (CDR)," United Technologies Hamilton Standard, 17 August 1995.

Specification Number S683–10142, "Prime Item Development Specification for the Airlock, *International Space Station* Alpha," Boeing Company, 15 April 1994.

Specification Number S683–29521, "Prime Item Development Specification for Habitation Element A (Hab A)," Boeing Company, 29 September 1994.

Specification Number S683–29523D, "Prime Item Development Specification for United States Laboratory, *International Space Station* Configuration Item Number, 683400A," Boeing Company, 28 March 1995.

SSP 41000B, "System Specification for the *International Space Station* Alpha," Boeing Defense and Space Group, 1 November 1994.

SSP 50011–01, "Concept of Operation and Utilization," Volume 1: Principles, Rev. B, 19 October 1994.

SSP 50104, "Portable Breathing Apparatus Standard Interface Control Document," 1 May 1995.

SS–HDBK–0001, Vol. 2, Draft 8.

Thompson, C.E., "Maintainability Program Source Data, Trace Contaminant Control Subassembly," Lockheed Missiles and Space Company, Space Systems Division, LMSC/F369707, Revision E, Volume 2, 4 August 1992.

"U.S. Lab Architecture Control Document, Volume 7: Temperature and Humidity Control, Revision New," D683–14719–1–7, Boeing, 20 December 1996

"U.S. Lab Architecture Control Document, Volume 8: Fire Detection and Suppression, Revision New," D683–14719–1–8, Boeing, 13 December 1996.

CHAPTER III: THE EUROPEAN, JAPANESE, AND ITALIAN SEGMENTS ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEMS

Balocco, P., "APM ECLSS Presentation," ECLSS Technical Interchange Meeting, Johnson Space Center, Houston, TX, 24–28 July 1995.

"Japanese Experiment Module (JEM) and Experiment Logistics Module (ELM) ECLSS Technical Briefing," Arthur Y. Hsu, Johnson Space Center, Houston, TX, 23 February 1995.

MLM–RP–AI–0084, "MPLM ECLS S/S Design Report," Alenia Spazio S.P.A., 8 February 1995.

MLM–RP–AI–0084, "MPLM ECLS S/S Design Report," Issue 03, 8 February 1995.

MLM–SS–AI–0026, "MPLM ECLS S/S Specification," Issue 03, 8 February 1995.

SSP 30255, "Baseline Configuration Document, Volume 2: Flight Element Configurations, Part 6: ESA Columbus Attached Pressurized Module," EuroColumbus, European Space Agency, 1993.

SSP 41160, "Segment Specification for the European Space Agency Attached Pressurized Module," 22 March 1994.

SSP 41164, "Italian Mini-Pressurized Logistics Segment," 19 March 1994.

SSP 41165, "Segment Specification for the Japanese Experiment Module," 9 March 1994.

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13. ABSTRACT *(Maximum 200 words)*

The *International Space Station (ISS)* incorporates elements designed and developed by an international consortium led by the United States (U.S.), and by Russia. For this cooperative effort to succeed, it is crucial that the designs and methods of design of the other partners are understood sufficiently to ensure compatibility. Environmental Control and Life Support (ECLS) is one system in which functions are performed independently on the Russian Segment (RS) and on the U.S./international segments. This document describes, in two volumes, the design and operation of the ECLS Systems (ECLSS) on board the *ISS*. Volume I is divided into three chapters. Chapter I is a general overview of the *ISS*, describing the configuration, general requirements, and distribution of systems as related to the ECLSS, and includes discussion of the design philosophies of the partners and methods of verification of equipment. Chapter II describes the U.S. ECLSS and technologies in greater detail. Chapter III describes the ECLSS in the European Attached Pressurized Module (APM), Japanese Experiment Module (JEM), and Italian Mini-Pressurized Logistics Module (MPLM). Volume II describes the Russian ECLSS and technologies in greater detail. These documents present thorough, yet concise, descriptions of the *ISS* ECLSS.

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